4. HIGH WINDS, FLOODS, AND OTHER EXTERNAL EVENTS

4.1 Introduction

This section summarizes the key results from 70 IPEEE submittals with regard to high winds, floods, and other (HFO) external events, including transportation and nearby facility accidents, and plant-unique hazards. External flooding events were evaluated in the IPEEE program, while internal flooding was addressed in the IPE program. Table 4.1 gives a list of the HFO-related external event topics discussed in NUREG-1407.

Table 4.1: Potential natural and man-induced events to be considered for HFO external events (from NUREG-1407)

Man-Induced Events	
Aircraft impact	
Industrial or military facility accident (offsite toxic or combustible/explosive gas/chemicals)	
Pipeline accident (onsite toxic or combustible/explosive gas)	
Release of chemicals from onsite storage	
Turbine-generated missiles	
Natural Events	
Avalanche	Internal flooding
Coastal erosion	Landslide
Drought	Lightning
Dust storms	Low lake or river water level
External flooding (e.g., high tide, lake, or river water level)	Meteorite
Extreme winds and tornadoes	Sandstorm
Fog	Seiche (oscillatory waves)
Forest fire	Severe temperature transients (hot or cold)
Frost	Snow
Hail	Storm surge
Hurricane	Volcanic activity (including volcanic ash)
Ice (blockage of intakes, etc.)	Waves
Intense precipitation	

4.1.1 Objectives

The objectives of this chapter are to discuss the HFO review findings reported in the licensees' submittals, and to identify insights gleaned from the staff's reviews of the submittals.

4.1.2 Organization

This chapter specifically addresses the HFO areas of the IPEEE, and is organized in the following seven major subsections.

- Section 4.1 provides an introduction including the objectives and organization of this chapter. This section also gives background information including some historical perspectives for HFO events, guidance for conducting the HFO reviews, and an overview of the results.

- Section 4.2 discusses the perspectives gleaned from the IPEEE evaluations of high winds, including tornadoes, tornado missiles, and hurricanes. Potential vulnerabilities associated with severe high wind conditions are discussed, including plant improvements that licensees have considered or implemented to reduce the plant risk associated with these events.

- Section 4.3 discusses the perspectives gleaned from the IPEEE evaluations of external floods, including intense rainfall resulting in site flooding and roof ponding; flooding from nearby bodies of water, including wave runup from rivers, lakes, and the ocean; potential flooding from postulated dam failures; and flooding as the result of snow melt. Potential vulnerabilities resulting from external floods are discussed with plant improvements that licensees have considered or implemented to reduce the plant risk associated with such flooding.

- Section 4.4 discusses perspectives gleaned from the IPEEE evaluations of accidents related to transportation or nearby industrial facilities. Potential vulnerabilities from such accidents are discussed with plant improvements that licensees have considered or implemented to reduce the plant risk associated with these types of events.

- Section 4.5 discusses other types of external events that can occur. This category includes events such as onsite hazardous material spills; hydrogen line breaks; effects from low-temperature conditions, such as icing and blockage of cooling water intake lines; blockage of drains and intakes from debris; other weather conditions, such as wind-blown sand and dust; and any other plant-unique hazard events.

- Section 4.6 discusses some general observations regarding HFO events. Topics included in this section are containment performance, unresolved safety issues (USIs) and generic safety issues (GSIs), human actions, HFO-related information gained from plant walkdowns, a summary of related plant improvements, general perspectives, and some perspectives regarding the impact of the HFO event analyses on plant safety.

- Section 4.7 provides a summary and conclusions gleaned from the HFO reviews.

4.1.3 Background

This section provides background information including a historical perspective for the HFO external events and a discussion of the guidance used in conducting reviews of these events.

4.1.3.1 Historical Perspectives on High Winds, Floods, and Other External Events

The primary regulatory basis governing the HFO-related design aspects of nuclear power reactors is contained in Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants." General Design Criterion (GDC) 2 defines design bases requirements for protection against natural phenomena. GDC 2 identifies the following performance criterion:

> Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.

In 1975, the NRC published the Standard Review Plan (SRP), which provides standardized review criteria to assist the staff in evaluating safety analysis reports submitted by license applicants. Since its first publication, the SRP has undergone several revisions (the latest being 1981) to incorporate new developments in design and analysis technology. The SRP sections that address plant safety issues relevant to the IPEEE HFO events include SRP Section 2.2.1, "Site Location and Description," and Section 2.2.2, "Identification of Potential Hazards in Site Vicinity." The review criteria in these SRP sections include the locations of transportation routes (water, rail, car) in the vicinity of the plant; pipelines that may contain hazardous materials; and fixed manufacturing, processing, and storage facilities. The review of these areas focuses on the potential for a release of hazardous material that could cause a fire, an explosion, or a threat to the habitability of the plant's control room. These two sections and other SRP sections that are relevant to the IPEEE HFO events are listed in Table 4.2.

There are also a number of regulatory guides that address the technical issues related to the IPEEE HFO events, as follows:

- Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants,"
- Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants,"
- Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants,"
- Regulatory Guide 1.115, "Protection from Low-Trajectory Turbine Missiles," and
- Regulatory Guide 1.117, "Tornado Classification."

Table 4.2: Standard review plan sections relevant to HFO events

SRP section	Title
2.2.3	Evaluation of Potential Accidents
2.3.1	Regional Climatology
2.3.2	Local Meteorology
2.4.1	Hydrologic Description
2.4.2	Floods
2.4.3	Probable Maximum Flood (PMF) on Streams and Rivers
2.4.4	Potential Dam Failures
2.4.5	Probable Maximum Surge and Seiche Flooding
2.4.6	Probable Maximum Tsunami Flooding
2.4.7	Ice Effects
2.4.10	Flooding Protection Requirements
2.4.11	Cooling Water Supply*
3.3.1	Wind Loading
3.3.2	Tornado Loadings
3.4.1	Flood Protection
3.4.2	Analysis Procedures
3.5.1.4	Missiles Generated by Nature Phenomena
3.5.1.5	Site Proximity Missiles (Except Aircraft)
3.5.1.6	Aircraft Hazards
3.5.2	Structures, Systems, and Components to Be Protected from Externally Generated Missiles
* SRP Section 2.4.11 refers to potential interference with the ultimate heat sink, such as ice blockage, debris, droughts, etc.	

The acceptance criteria for each HFO area given in the SRP are specifically tied to the corresponding GDCs for that topic and the regulatory guides that address that area. Hence, there is a close connection between the review of HFO events and the other related NRC regulatory guidance.

There are two other NRC programs that are directly related to the IPEEE HFO events. These programs are the Generic Safety Issues (GSIs) Program and the Systematic Evaluation Program (SEP). GSI-103, "Design for Probable Maximum Precipitation" (PMP), involved an evaluation of a plant's capability to withstand severe rainfall using updated site-dependent PMP values developed by the National Oceanic and Atmospheric Administration. GSI-172, "Multiple System Responses Program (MSRP)," addressed a number of generic plant safety concerns. One of the MSRP issues that directly relate to HFO events is the effects of flooding and/or moisture intrusion on non safety-related and safety-related equipment. An aspect of the HFO reviews was to determine if the GSIs discussed above could be verified on a plant-specific basis as part of the IPEEE program.

The SEP was initiated in the mid-1970s. This program recognized that many safety criteria, including those associated with HFO events, had evolved since the initial licensing of the earliest nuclear power plants. The purpose of the SEP was to develop a systematic and documented basis for the safety of the older plants by comparing them to the current licensing criteria.

Among the many technical issues that were included as a part of the SEP were six issues related to the HFO events. These issues were (1) dam integrity and site flooding, (2) site hydrology and ability to withstand floods, (3) industrial hazards, (4) tornado missiles, (5) severe weather effects on structures, and (6) design codes, criteria, and load combinations. The IPEEE-related SEP issues are described in more detail in Section 5.4.7 of this report.

The following section of this report provides guidance for conducting IPEEE HFO reviews. As discussed in NUREG-1407, one of the approaches that a licensee could use in analyzing of the HFO events was to determine if the plant conforms to the guidance in the NRC's 1975 Standard Review Plan coupled with a plant walkdown. This approach was widely used by licensees in performing their evaluations of the HFO events.

4.1.3.2 Guidance for Conducting IPEEE HFO Analyses

Guidance for conducting HFO analyses for the IPEEEs is provided in Section 5 of NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities" (NUREG-1407). In particular, NUREG-1407 recommends a progressive screening approach to identify potential HFO-related vulnerabilities at U.S. nuclear power plants. This progressive screening approach, summarized below, represents a series of steps or analyses in increasing level of detail and effort.

- Review the plant-specific hazard data and licensing basis and determine if any significant changes that could impact the IPEEE have occurred since the issuance of the operating license.

- Determine whether the plant conforms to the guidance in the NRC's 1975 Standard Review Plan (SRP) (NUREG-0800), and perform a plant walkdown.

- If the plant does not conform to the 1975 SRP guidance, one or more of the following optional steps may be taken:

  - Determine if the hazard frequency of the original design is acceptably low, by demonstrating that the hazard frequency is less than 1E-5 per year.

  - If the event cannot be screened out on the basis of hazard frequency, perform a bounding analysis. Such an analysis should be performed using conservative parameters, and is intended to show that the hazard would not result in a bounding CDF contribution above the screening criterion of 1E-6 per reactor-year (ry).

– Perform a PRA.

- High winds, floods, transportation, and nearby facility accidents are to be explicitly addressed in each licensee's IPEEE submittal, while "other" additional external events are to be addressed if they are applicable to a specific site.

- An analysis of containment performance for HFO events is not needed unless the licensee predicts or identifies plant-unique accident sequences that are different from those determined by the internal events IPE.

- As an alternative to the above options, a licensee may request that the staff review any other systematic examination method to determine its acceptability for IPEEE purposes.

These various options are graphically shown in Figure 4.1, which is taken from NUREG-1407.

4.1.4 Overview of Results

A summary of the HFO-related IPEEE results for the 70 plants reviewed is given in Table 4.1 of Volume 2 of this report. This table includes the method used by each licensee to evaluate HFO events, the estimated CDF, if reported, and HFO-related improvements that licensees have implemented or planned. As indicated in this table, all licensees have addressed a range of HFO events at their plants.

In the majority of the HFO event analyses, licensees have screened out these events on the basis of qualitative assessments, consistent with one of the accepted approaches given in NUREG-1407. A qualitative assessment typically involved demonstrating conformance with the 1975 SRP criteria (or for several plants the criteria in the updated 1981 SRP) coupled with a plant walkdown. The purpose of the walkdown is to identify any changes in the plant configuration from the original design basis that may impact the IPEEE evaluation and also to identify any specific plant areas that may not necessarily have been part of the design basis but could significantly impact the IPEEE evaluation (e.g., a roof design that could potentially be overloaded during heavy rainstorms because the drains are susceptible to being blocked with debris). There are three forms of quantitative analyses that licensees have used in the HFO-related IPEEEs, each involving a different level of detail and resulting in a different type and amount of information. These three evaluation methods (analysis of hazard frequency, bounding analysis of estimated CDF contributors, and PRA) are described in Section 4.1.3.2 and Figure 4.1. As in other applications, licensees that performed PRAs for HFO-related studies have used varying degrees of conservatism, some with best-estimate parameters and others with more conservative values.

Table 4.3 shows the relative distribution of the evaluation methods used by the licensees in performing their HFO reviews. This table summarizes the methods chosen by the licensees for analyzing the topical event categories of: high winds in general, tornadoes, tornado-generated missiles, floods, other external events in general, chemical releases, hydrogen explosions, and aircraft crashes. Table 4.3 also indicates that most of the HFO-related IPEEE studies (approximately 80%) were performed using the qualitative screening method,

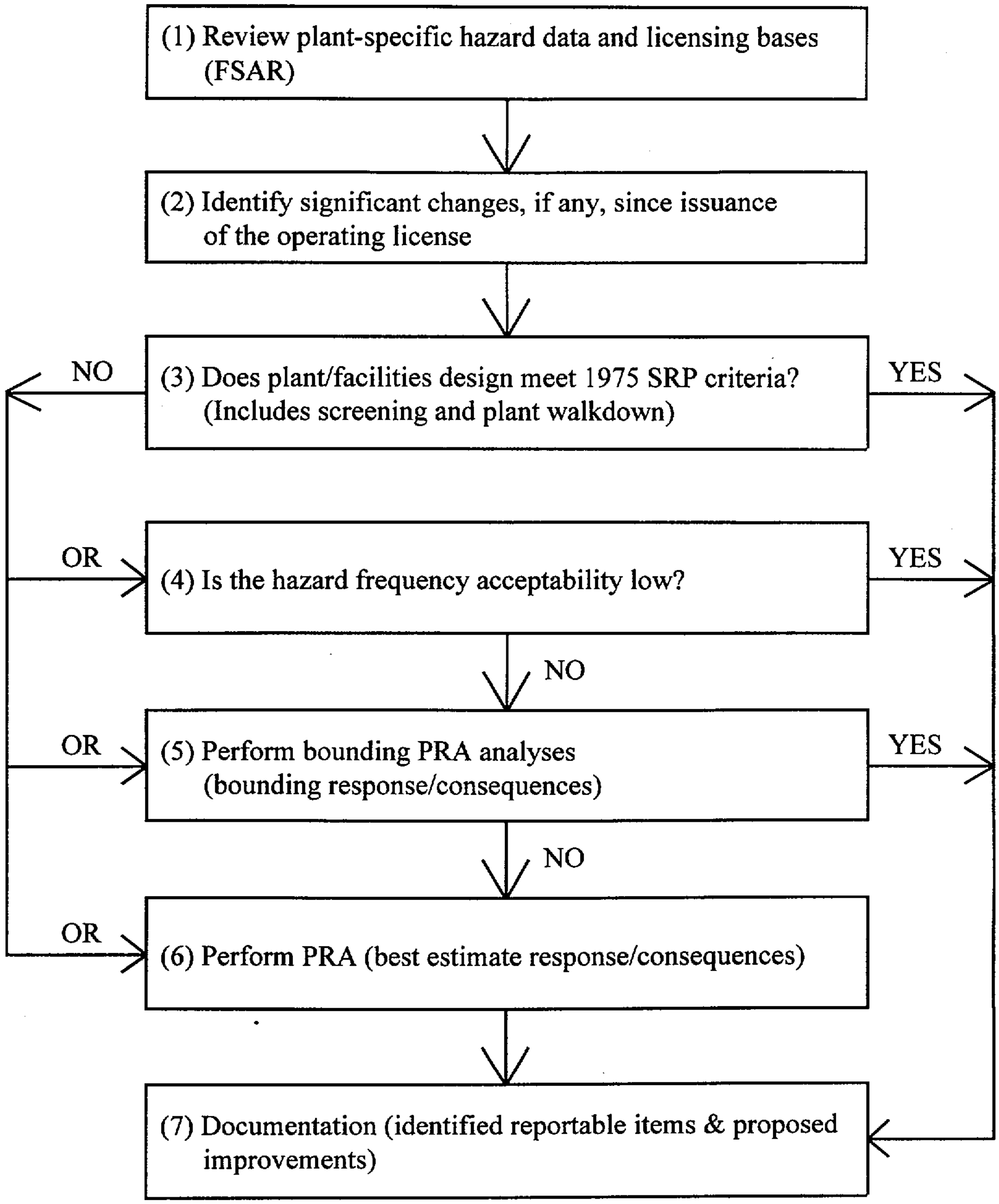

Figure 4.1 Recommended IPEEE approach for high winds, floods, and other external events

as allowed in NUREG-1407. The PRA applications, including both full and partial bounding PRAs, accounted for roughly 15% and, lastly, the initiating event hazard frequency method was used least frequently (less than 5%).

None of the 70 IPEEE submittals identified any HFO-related vulnerabilities; however, 34 submittals reported that they had either made, or were considering, a total of 64 HFO-related plant improvements; 36 submittals reported that they had not identified any needed improvements. Tables provided in this chapter show the number of improvements for each event category, and the number of plants making improvements for each category of events.

Section 4.6 summarizes the general observations and insights pertaining to the HFO IPEEE submittals.

Table 4.3: Licensees' methods of analysis for HFO external events (by topic)

Event category	Number of applications by analysis type		
	Qualitative screening[1]	PRA[2]	Hazard frequency[3]
High winds (general)	55	13	2
Tornadoes	51	17	2
Tornado-generated missiles	56	12	2
Floods	58	12	0
Other events (general)	60	7	3
Chemical releases	57	10	3
Hydrogen explosions	59	8	3
Aircraft crashes	58	8	4

Notes:
1. As allowed by NUREG-1407, this approach involves confirming that the plant is in conformance with the 1975 SRP criteria coupled with a walkdown to confirm that changes have not occurred at the plant that would impact on the IPEEE or that there are important plant-unique situations that should be considered.
2. Some of the applications of PRA used best-estimate input parameters, and others used some bounding parameters to simplify the analysis.
3. In this approach, an event is screened out if the calculation of the initiating frequency (e.g., the likelihood of a damaging tornado event) has an estimated frequency below some screening value (a typical value used is 1E-5 events/year).

4.2 High Winds

4.2.1 Introduction

The external events category of high winds comprises tornadoes, hurricanes, and straight winds.

4.2.2 High Winds Quantitative Results

Among the 17 plant submittals that reported a CDF from high winds, the results have ranged from less than 2E-7/ry to 6E-5/ry.

Typically, the dominant CDF sequence associated with high winds involved a loss of offsite power (LOOP) in combination with random failure of emergency ac power. Other random failures that licensees reported as being significant contributors to CDF for high wind events include the loss of service water, auxiliary feedwater, feed-and-bleed cooling, and high-pressure injection. In addition, one plant postulated that wind-generated missiles could fail the diesel generators, service water system condensate storage tank, or ventilation system, thereby leading to core damage. Another plant identified the diesel fuel oil transfer pumps and lines as being exposed to tornado-induced missiles.

The review process revealed that some licensees had employed optimistic assumptions in their analysis of high winds. In response to related RAIs, the licensees either revised their analyses or provided information to show that their assumptions were appropriate. For example, in one submittal, the licensee's treatment of direct winds initially screened out wind speeds from 108 to 125 miles per hour. However, upon subsequent analysis, the licensee found that such wind speeds could lead to station blackout, and increased the plant's CDF contribution from 2E-6/ry to 8E-6/ry.

4.2.3 High Winds Qualitative Results

As seen in Table 4.3, qualitative analysis involving the demonstration of conformance with the 1975 SRP was used much more frequently than either PRA (full and bounding assessment) or hazard frequency screening for high winds (i.e., 55 cases versus 13 and 2 cases, respectively).

4.2.4 Plant Improvements for High Winds

The plant improvements that the licensees reported to increase protection against the effects of high winds included 7 procedural improvements and 10 plant hardware improvements. Table 4.5 of this volume lists the individual improvements for high winds which are also identified in the plant-specific summaries in Table 4.1 of Volume 2.

4.2.5 General Insights for High Winds

As would be expected, the incidence of a specific type of high wind that is of significant magnitude to cause power plant damage is very region-specific in the United States. Hurricanes are the dominant potentially damaging high wind source in the coastal areas, while tornadoes dominate inland, particularly in the Midwest and South. One of the more damaging ways in which high wind effects contribute to plant CDF is through impact of wind-generated missiles, particularly tornado-generated missiles. Seventeen plant improvements related to high winds were cited by the licensees as a result of their IPEEEs. This accounted for approximately 27% of all of the HFO-related improvements. See Table 4.4 for a summary of the relative distribution of the HFO-related improvements.

Table 4.4: Total number of plant improvements for high winds, floods, and other external events*

External event	Number of improvements	Percentage
High winds	17	27%
External flooding	32	50%
Transportation or nearby facility accidents	5	8%
Other external events including plant-unique hazards	10	15%
Total	64	100%

* This table gives the total number of improvements cited in the submittals for all 70 IPEEE plants. These improvements include both procedural and hardware improvements. Some of the improvements cited by the licensees in their submittals were still under consideration at the time the licensees sent their IPEEEs to the NRC. Therefore, the number of actual improvements that have been implemented is not known, but is likely to be somewhat less than 64. A small number (less than five) of the improvements had been implemented before the IPEEE, but were IPEEE-related.

Table 4.5: Plant improvements to protect against high winds

Procedural improvements
Special plant procedures
Arrangement for the timely delivery of additional diesel generator fuel oil during storms
Emergency procedures to inspect diesel generator fuel oil transfer pumps and to isolate oil leakage and provide for makeup after a high wind event
Special training sessions for plant personnel, including training in the use of redundant instrumentation locations
Additional sheltering plans for plant personnel
Revised emergency procedures based on lessons learned from Hurricane Andrew
Emergency procedures to prevent ventilation failures during hurricanes
Hardware improvements
Tornado protection of the diesel generator exhaust system
Protection for the diesel generator room air supply
Addition of an air-cooled diesel generator (added before the IPEEE)
Addition of a tornado missile shield in the door of a technical support center
Addition of a tornado missile shield for an opening of an auxiliary building
Protection of cooling ducts and dampers in the control and diesel generator rooms during high wind conditions
Modifications to strengthen the diesel generator exhaust stacks
Improved mechanical hold downs for hydrogen tanks
Modifications to exterior doors to withstand pressure differentials during high winds
Strengthening of exhaust stacks of nearby fossil plant to prevent collateral damage from high winds

4.3 External Floods

4.3.1 Introduction

Sources of external floods are intense rainfall (including hurricanes); dam failures; wind-driven waves from lakes, rivers, or the ocean; abnormally high water levels from the same; and melting snow. Potential damage modes are site flooding resulting in water ingress into areas housing vulnerable safety-related equipment and water ponding on roofs that could potentially fail from the increased roof loading.

4.3.2 External Floods Quantitative Results

Of the licensees' submittals, 12 reported CDF contributions for external flooding ranging from about 2E-8/ry to about 7E-6/ry. Typically, floods induced by dam breaks, hurricanes, or intense precipitation have been treated as leading to a LOOP, which the licensees usually assumed to be irrecoverable, and additional random failures could then lead to core damage. Other submittals listed additional flood-related damage, including the loss of function of the intake structure; failures of diesel fuel oil transfer pumps; and potential failures of safety-related equipment in the diesel generator, auxiliary, and turbine buildings.

4.3.3 External Floods Qualitative Results

Just as for high winds, licensees used the qualitative screening approach more often than PRA or hazard frequency screening (58 cases versus 12 and 0 cases, respectively). In few instances where flood hazards were screened out, the IPEEE review process revealed that a relatively small increase in the critical flood level (perhaps just a few inches) could result in a significant change in the predicted annual rate of flood occurrence, such that these events could no longer be screened out, and additional analysis would then be needed to assess the consequences. On the other hand, many of the flooding assessments were conservative in that the licensees assumed that the effects from a number of possible conditions were cumulative (e.g., assuming a concurrent combination of peak wind-driven wave heights and peak high-water levels). Given the substantial uncertainties involved in developing site-specific flood hazard curves, a consideration of possible combinations of multiple effects causing a range of flood levels would have enhanced the robustness of some of the licensee's analyses and lent greater confidence to their findings.

Where applicable, most submittals considered and screened out potential failures of upstream dams that could lead to flooding at the plant site.

A few licensees proposed flood-related countermeasures that may be optimistic. For example, one licensee took credit for sandbagging up to a level of 9 feet. In several other submittals, flood barriers made of various construction materials, such as logs or concrete beams, were credited with being effective for preventing flooding, but the submittals did not discuss whether the licensees performed confirmatory testing to verify the effectiveness of certain of these mitigating actions.

4.3.4 Plant Improvements for External Floods

Plant improvements that were cited to provide further protection against flooding included 15 procedural improvements and 17 plant hardware improvements. Table 4.6 of this volume lists the individual flood-related improvements, which are also identified in the plant-specific summaries in Table 4.1 of Volume 2.

4.3.5 General Insights About External Floods

As for high winds, the effects of flooding are seen to be very region-specific and are more common in certain areas of the United States than in others. Plant sites 1n coastal locations are most susceptible to hurricane-induced flooding, as well as high precipitation levels. Certain rivers and lakes are more prone to have combinations of high winds and associated waves combined with high water levels, and other areas in the Northern and Western United States are subject to heavy snows with subsequent melting and flooding. As indicated, this category of the HFO-related events accounted for more of the cited plant improvements (approximately 50%) than any other HFO-related area.

Table 4.6: Plant improvements to protect against external floods

Procedural improvements
Improved emergency procedures for flooding conditions
Increased maintenance of drainage structures
Improved plant flood mitigation procedures
Increased inspection of roof drains
Procedures and inspections associated with the expeditious installation of special flood doors when needed
Special procedures for removal of snow and ice
Surveillance of a drain flapper valve for drainage from a control building
Evaluation of closure times for flood gates to aid in emergency planning
Revised procedures based on lessons learned regarding flooding from Hurricane Andrew
Procedures regarding water drainage from the turbine building during heavy rainfall
Procedures to prevent water flow from the turbine building into the main control room
Improved procedures to protect against local river flooding
Improved emergency operating procedures in the event of a dam failure
Hardware improvements
Scuppers in parapet walls to promote drainage and reduce roof ponding loads during heavy rainfall
Provisions for portable pumps
Upgrading flood-resistant doors
Provision for sandbags
Sealing of conduits
Addition of weather stripping to doors in buildings housing safety-related equipment
Addition of screens on equipment hub drains in a 480V switchgear room to preclude foreign material intrusion
Flood protection of a service water pump motor
Alteration of local site topography to reduce potential site flooding
Addition of a seiche (oscillatory wave action) protection barrier to protect the fuel oil transfer pumps for the diesel generators from flooding
Improved penetration seals to protect against potential flooding between service and auxiliary buildings
Modifications to the service water pump house roof to allow existing scuppers to drain excess rainwater more effectively
Refurbishment of existing flood walls and stop logs
Raised elevation of diesel generator fuel oil transfer pumps to protect against hurricane surge
Sealing of underground conduits to the switchgear rooms against water intrusion
Sealing penetrations in the diesel fuel oil transfer pump house to protect transfer pumps
Addition of a pump in the cooling tower area to remove excess water during heavy rainfall

4.4 Accidents Involving Transportation or Nearby Facilities

4.4.1 Introduction

Examples of events in this category include accidents involving hazardous chemical spills; fires or explosions from railway shipping or truck transport in the area of the plant (typically within a 5-mile distance); hazardous chemical spills, fires, or explosions from commercial facilities in the vicinity of the plant (e.g., chemical processing or storage plants, hydrogen storage tanks, etc.); and aircraft crashes.

4.4.2 Results of Analyses

Although only a few submittals document PRA results or CDF bounding assessments for these specific types of accidents (e.g., aircraft crashes), none of the submittals identified a CDF from accidents involving transportation or nearby facilities above the NUREG-1407 screening criterion of 1E-6/ry.

The large majority of the licensees performed qualitative as opposed to PRA or hazard frequency screening for their IPEEE transportation analyses. As observed for the treatment of the other HFO events, most submittals did not report walkdown procedures, walkdown team composition, or detailed walkdown findings. Many of the submittals primarily relied on existing analyses and documents as the basis for screening out transportation and nearby facility accidents.

4.4.3 Plant Improvements for Transportation or Nearby Facility Accidents

Plant improvements that were cited to protect against these types of events included just three procedural improvements and two plant hardware improvements. As indicated in Table 4.4, this category accounted for the fewest number of HFO-related plant improvements (8%). Table 4.7 of this volume lists the individual improvements related to transportation and nearby facility accidents, which are also identified in the plant-specific summaries in Table 4.1 of Volume 2.

Table 4.7: Plant improvements to protect against transportation and nearby facility accidents

Procedural improvements
Addition of plant guidelines to exclude flights over the plant by company pilots
Addition of restrictions to exclude all flights over the plant
Coordination with the U.S. Coast Guard to prevent further shipping of explosive materials on a nearby shipping channel
Hardware improvements
Addition of a backup cooling water intake structure for added protection against barge accidents (added before the IPEEE)
Addition of concrete barriers placed around a propane tank near the diesel generator rooms to protect against possible vehicle impact and subsequent explosions and fires

4.4.4 General Insights for Transportation or Nearby Facility Accidents

Transportation and nearby facility accidents do not vary regionally as much as weather-related external events, such as high winds and flooding. All areas of the United States where plants are located may have nearby roadways, rail traffic, water traffic, air traffic, and industrial facilities. While these types of events were not found to account for a significant risk contribution in any of the IPEEE submittals, and the relative number of plant improvements was much smaller than for the other HFO-related topics, these classes of accidents have rather unique aspects. That is, the plant-specific situation could change rather quickly. Fore example, a company could begin to transport hazardous materials by a route (by water, rail, or roadway) sufficiently close to the plant to pose a hazard, or a nearby industrial facility could establish a new storage facility for hazardous materials on its property but close enough to the plant to pose a potential risk. These changes could conceivably be made without the knowledge of the plant safety personnel, and those making the changes may not be particularly sensitive to the potential impact on the plant's safety. Although these types of accidents have not been found to represent a significant risk in the IPEEEs, this emphasizes the need for communication between licensees and nearby facilities to ensure the use of up-to-date information.

4.5 Other External Events Including Plant-Unique Hazards

4.5.1 Introduction

Besides high winds, floods, and transportation and nearby facility accidents, a wide variety of less likely other external events could possibly affect the plant risk, and these required consideration in the IPEEE evaluations. Table 4.1 gives a list of other types of events. Although most of these other events could easily be screened out, a few were found to have an impact on a site-specific basis as discussed below.

4.5.2 Other External Events Quantitative and Qualitative Results

As seen in Table 4.3, only a few (seven) licensees reported quantitative CDF estimates for this category of external events. One submittal (Haddam Neck) reported a CDF contribution of 8E-6/ry from lightning and 7E-6/ry from snow and ice. Lightning was assumed to cause a LOOP, with a number of other random failures being required to result in core damage. In the ice and snow analysis, the licensee found that the screen house, service building, and primary auxiliary building did not have roof load capacities much more than the snow load for a 100-year return interval. However, critical equipment failures attributable to roof collapse, combined with a number of other random failures, were required to lead to core damage.

NUREG-1407 did not require an explicit evaluation of HFO events other than high winds, external flooding, and accidents involving transportation or nearby facilities. Consequently, some submittals did not report an analysis of "other" HFO events. For those that did, most screened these events using qualitative screening techniques (e.g., showing conformance with the 1975 SRP criteria). For these other events, the number of qualitative screening applications compared with PRA and hazard frequency screening was 60, 7, and 3, respectively. In submittals that reported risk results for some "other" HFO event, most were found to have CDF contributions less than the NUREG-1407 screening criterion of 1E-6/ry.

Two submittals reported the existence of a plant-unique hazard related to failure of downstream dams and related loss of a cooling source. In one case, the hazard was screened out since it is covered as a design basis accident. In the other case, the hazard is also a design basis event, but the licensee estimated an initiating event frequency and performed a bounding CDF analysis on the basis of the applicable conditional core damage probability (CCDP) in order to screen out the hazard.

4.5.3 Plant Improvements for Other External Events

The improvements for this category included six procedural and four plant hardware improvements. As indicated in Table 4.4, the 10 improvements in the "other" category accounted for approximately 15% of all of the HFO-related improvements. Table 4.8 of this volume lists the individual improvements for this category, which are also identified in the plant-specific summaries in Table 4.1 of Volume 2.

Table 4.8: Plant improvements to protect against other external events

Procedural improvements
Special report regarding onsite hazards from potentially dangerous materials
Notice regarding the onsite storage and transportation of hazardous materials
Evaluation of control room habitability regarding plans for storing hazardous materials onsite
Increasing the distance from a recently enlarged hydrogen storage system to the nearest safety-related equipment
Guidance to prevent the buildup of hydrogen gas in letdown storage tank rooms
Procedures to prevent stacking of containers in close proximity to safety-related equipment
Hardware improvements
Modifications to prevent ice formation on service water pumps serving the diesel generators
Addition of screens on drains to prevent foreign material intrusion into safety-related equipment spaces
Modifications to ventilation system exhausts systems to protect against potential combustible gas explosions
Modifications to a plant intake structure to prevent blockage from detritus (debris)

4.5.4 General Insights About Other External Events

While most plants did not report a significant hazard contribution attributable to these types of events, and most completely screened out this HFO category, there was one notable exception. Lightning and hazards associated with snow and ice were reported to have a relatively high CDF contribution at Haddam Neck (i.e., greater than the NUREG-1407 screening criterion of 1E-6/ry). While the CDF contributions for these events were estimated to be above the screening criterion at Haddam Neck, they still represent a small fraction of the overall plant CDF and are not large enough to be considered vulnerabilities. As indicated, this category of potential plant hazards is often unique to the plant and, in some cases, is regional in that the hazards are weather related.

4.6 General Observations and Insights about HFO External Events

4.6.1 Containment Performance Perspectives

None of the 70 IPEEE submittals identified any plant-unique accident sequences associated with containment performance that are different from those determined by the internal events IPE. Consistent with the guidance in Section 5.2 of NUREG-1407, no additional containment performance is needed for HFO events.

4.6.2 Unresolved Safety Issues and Generic Safety Issues

Unresolved safety issues (USIs) and generic safety issues (GSIs) are discussed in depth in Chapter 5 of this report. Those issues pertaining particularly to the HFO part of the IPEEE review are discussed briefly below.

All submittals provided some discussion concerning GSI-103, "Probable Maximum Precipitation." For this issue, some of the licensees stated that they had taken measures to protect roofs of safety-related buildings from the effects of roof ponding predicted as a result of intense local precipitation (e.g., the addition of scuppers to aid in draining the water). As noted in Table 5.2 and Section 5.4 of this report, three plants have not completely verified GSI-103.

The HFO IPEEE submittals did not explicitly discuss other GSIs or USIs. Nonetheless, certain information provided in the submittals is considered relevant for addressing issues associated with GSI-156, "Systematic Evaluation Program (SEP)," and GSI-172, "Multiple System Responses Program (MSRP)," as discussed below.

4.6.2.1 GSI-156, Systematic Evaluation Program

This generic issue has five sub-issues related to HFO events that are discussed below.

- *Dam Integrity and Site Flooding*. When applicable to the plant, HFO IPEEE submittals generally discussed the potential for, and effects of, site flooding as a result of independent or combined failures of upstream and downstream dams. Two submittals also considered the potential for loss of cooling water caused by failure of an onsite dam.

- *Site Hydrology and Ability to Withstand Floods.* HFO IPEEE submittals generally provided discussions that are directly relevant to this issue in their assessments of floods.

- *Industrial Hazards*. HFO IPEEE submittals generally provided discussions that are directly relevant to this issue in their assessment of accidents involving transportation and nearby industrial facilities.

- *Tornado Missiles*. HFO IPEEE submittals generally provided discussions that are directly relevant to this issue in their assessment of high winds and tornadoes.

- *Severe Weather Effects on Structures*. In general, HFO IPEEEs screened out the effects of direct winds and flooding on plant structures. Nonetheless, where applicable, the submittals generally provided relevant information concerning the effects of wind-induced missiles on those structures.

4.6.2.2 GSI-172, Multiple System Responses Program

With regard to GSI-172, the only HFO-related issue regarding GSI-172 is the effects of flooding and/or moisture intrusion on non safety-related and safety-related equipment. With respect to safety-related equipment, HFO IPEEE submittals generally provided discussions that are directly relevant to this issue in their assessment of floods. However, the submittals generally did not discuss flooding or moisture intrusion effects on non-safety-related equipment. This omission is not important from an IPEEE perspective since these effects do not contribute significantly to the plants' external event CDFs.

4.6.3 Human Actions

Where applicable, the HFO submittals documented operator recovery actions to mitigate the effects of HFO-induced plant transients. In those instances, the important operator recovery actions included recovery of offsite power or diesel generators given a tornado- or high-wind-induced LOOP, and use of sandbagging or installation of stop logs to mitigate an external flood. In some cases, the licensees' assessments of recovery actions may have been somewhat optimistic. The submittals did not discuss whether licensees performed confirmatory testing to verify the effectiveness of certain of these mitigating actions. However, as indicated in Section 4.3.3, flooding analyses tended to include conservative assumptions and, in addition, flooding levels do not generally change rapidly for topological configurations around plants. Plant operators should have time to initiate emergency actions (e.g., including plant shutdown) if conditions require such actions.

4.6.4 Walkdown Perspectives

Most of the HFO submittals provided some general description regarding walkdown findings. One licensee reported that they believed that the updated FSAR data constituted a more reliable information source than a plant walkdown. Most of the submittals reviewed did not provide specific detailed information regarding either walkdown findings or walkdown team composition. Licensees employed walkdowns to confirm that no significant changes have occurred since the plant operating license was issued. Specifically, walkdown findings noted in regard to flooding events included the identification of two conduits for flood entry into critical structures, the discovery that loads on the roof of a spent fuel cooling pool from roof ponding could potentially exceed the roof's design load, and identification of flood pathways (including non-water-tight doors). Walkdown findings pertaining to high winds consisted primarily identifying exposed components and nearby objects for wind-induced missiles.

4.6.5 Summary of Plant Improvements

Procedural enhancements related to HFO events have included provisions for sandbagging, closing or welding doors, hooking up pumps, providing new electrical circuits to reduce the risk from flooding, and provision for routine inspection and maintenance of drains. Two submittals reported that the licensees were considering the development of severe accident management guidance to reduce the risk of high winds. One submittal indicated development of guidance to ensure that a flood door can be installed in 8 hours, for the purpose of reducing flooding risk.

Hardware improvements include (among others) refurbishing a flood wall, strengthening non-safety stacks to prevent collapse onto safety structures in high-wind events, installing weather stripping and other modifications to enhance flood protection at entry pathways, replacing drain screens, and providing equipment (such as portable water pumps) to enhance flood protection. At least one HFO submittal noted that hardware changes that had been implemented as a result of their IPE analyses (i.e., the addition of diesel generators) have also reduced the risk associated with HFO events.

Overall, for most licensees, the HFO IPEEE program has resulted in a greater level of appreciation of the potential risk impact of high winds and tornadoes, external flooding, and other external initiators.

4.6.6 General Perspectives

As shown in Table 4.1 of Volume 2, the CDF estimates for high winds (including tornadoes) and external flooding have been found to range from 2E-8/ry to 6E-5/ry. Conservative bounding analysis estimates of CDF for high winds and external floods have been reported and, while the associated risks were not categorized as "vulnerabilities," they have resulted in a number of plant improvements (see Table 4.1 of Volume 2; Tables 4.4, 4.5, 4.6, 4.7, and 4.8 of this volume; and Sections 4.2.4, 4.3.4, 4.4.4, and 4.5.4 of this volume). All IPEEE submittals screened out accidents involving transportation and nearby facilities.

Additional general review observations pertaining to HFO submittals include the following.

- Licensees' application of PRA techniques in HFO IPEEEs has varied considerably in scope, detail, and rigor. Simplified PRA approaches have generally been implemented, whereas to a lesser extent, detailed state-of-the-art PRA studies have been performed for some or all of the HFO initiators at a plant.

- Where the HFO IPEEE submittals have adopted the use of PRA methods or applicable PRA bounding analyses, licensees have commonly used the IPE conditional core damage probabilities (CCDPs) for events such as the loss of offsite power or loss of service water. However, the accident conditions associated with the IPEEE HFO events can be significantly different than the IPE conditions for these events. In certain cases, the accident sequences and associated CCDPs used to assess the HFO events may not have reflected the potential for the degradation of equipment performance as a result of conditions such as high winds or floods (particularly on exposed components). Consequently, in some of these cases, the resulting quantitative CDFs may have been underestimated, but not enough to mask a vulnerability.

- The HFO events are, by nature, somewhat different than the seismic and fire external events in the following respects. Certain HFO events can involve changes in the external environment that take place over time. An example of this is one case where a licensee reported that they discovered that explosive materials were being shipped on a nearby waterway. The licensee reported that when this was discovered, arrangements were made with the U.S. Coast Guard to prevent a recurrence. As discussed earlier, these types of events have not been found to be a significant risk contributor in the IPEEEs, but they emphasize the need for communication between licensees and other transportation and nearby facilities to ensure the use of up-to-date information.

4.6.7 Impact of the IPEEE HFO External Events Program on Plant Safety

Although no IPEEE submittal reported any HFO-related vulnerabilities, the HFO IPEEEs have resulted in numerous improvements in the form of procedural enhancements, severe accident management guidelines, and hardware improvements. Table 4.4 of this volume gives the number of improvements that licensees identified for the major IPEEE event categories; Tables 4.5, 4.6, 4.7, and 4.8 list the individual improvements by HFO topic; and Table 4.1 of Volume 2 lists the improvements on a plant-specific basis.

Given that many licensees reported improvements associated with HFO events, the HFO IPEEE program has had a significant impact on improving plant safety. Of the 70 plant submittals, 34 cited a total of 64 individual HFO-related improvements. Except for one case (Salem), the submittal did not provide information to quantify the reduction in CDF that resulted from these improvements. In the case of Salem, the licensee improved door seals to prevent flooding into a building that houses safety-related equipment. The IPEEE submittal reported that the CDF contribution was reduced from approximately 1E-4/ry to 1E-7/ry as a result of this improvement. Perhaps most important, it is clear from the documentation provided in the submittals that licensees' efforts to assess the potential hazards from HFO-related events have enhanced the knowledge of plant personnel regarding these types of events specifically for their plants.

4.7 Summary and Conclusions

For those cases where licensees performed PRAs or CDF bounding analyses, the estimated CDF results varied from plant to plant as demonstrated by the following information.

- For high winds and tornadoes, the plant-specific CDF results vary from less than 2E-7/ry to 6E-5/ry.

- For external flood events, the plant-specific CDF results for 12 plants vary from about 2E-8/ry to about 7E-6/ry.

- For transportation and nearby facility accidents, 8 plants reported that the plant-specific CDF results from PRA studies or bounding analyses are below the NUREG-1407 screening criterion of 1E-6/ry.

- One submittal (Haddam Neck) reported bounding analysis CDF results of 8E-6/ry for lightning events and 7E-6/ry for snow and ice.

- One submittal (South Texas) reported CDF results of 8E-6/ry for a chemical release from a nearby chemical facility.

- One submittal (Salem) reported a plant improvement that reduced the external events CDF by three orders of magnitude from approximately 1E-4/ry to approximately 1E-7/ry. The plant modification cited was the improvement of door penetration seals between the service and auxiliary buildings to protect against external flooding.

Regarding HFO-related plant improvements, 34 of the 70 plant submittals cited a total of 64 individual improvements. Sixteen plants cited more than one HFO-related improvement with one plant (Turkey Point) indicating that they were considering as many as five improvements. These improvements are summarized in Tables 4.4 through 4.8 in this volume and on a plant-by-plant basis in Table 4.1 of Volume 2. Thirty-six plants reported no HFO-related improvements.

All HFO evaluations reviewed screened out accidents involving transportation and nearby facilities, as well as other plant-unique hazards when encountered.

Of the 70 IPEEE submittals, most indicated that some type of walkdown was performed for HFO events during the IPEEE. However, one submittal stated that the licensee believed that a review of the updated FSAR data constituted a more reliable information source than a plant walkdown. The submittals usually did not provide detailed descriptions of the walkdown procedures and results.

As discussed in Section 4.6.7, the licensees' evaluations of HFO events have not identified any vulnerabilities to these type of events. However, the extent of the documentation submitted by the licensees regarding their evaluations, and the list of HFO-related plant improvements, suggest that the IPEEEs have significantly contributed to the licensees' understanding of, and preparation for, potential HFO events.

5. UNRESOLVED SAFETY ISSUES AND GENERIC SAFETY ISSUES

5.1 Introduction

This chapter discusses the unresolved safety issues (USIs) and generic safety issues (GSIs) that were addressed under the IPEEE program. Specifically, in accordance with Supplement 4 to Generic Letter (GL) 88-20 and the associated guidance in NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," the NRC requested that licensees provide information to address the following issues:

- USI A-45, "Shutdown Decay Heat Removal Requirements,"
- GSI-103, "Design for Probable Maximum Precipitation,"
- GSI-131, "Potential Seismic Interaction Involving Movable In-Core Flux Mapping System Used in Westinghouse Plants,"
- GSI-57, "Effects of Fire Protection System Actuation on Safety-Related Equipment," and
- Sandia Fire Risk Scoping Study (FRSS) issues.

In addition, the four other GSIs listed below have external event aspects, but were not specifically identified as issues to be verified under the IPEEE program and, therefore, were not explicitly discussed in Supplement 4 to GL 88-20 or NUREG-1407. After issuing the generic letter, the NRC evaluated the scope and the specific information requested in the generic letter and the associated IPEEE guidance. The NRC concluded that the plant-specific analyses requested in the IPEEE program could also be used, through a satisfactory IPEEE submittal review, to evaluate and verify the external event aspects of the following safety issues:

- GSI-147, "Fire-Induced Alternate Shutdown/Control Room Panel Interactions,"
- GSI-148, "Smoke Control and Manual Fire-Fighting Effectiveness,"
- GSI-156, "Systematic Evaluation Program (SEP)," and
- GSI-172, "Multiple System Responses Program" (MSRP).

It should be noted that there is some overlap among the issues discussed in this chapter and, although the majority of these issues are covered within the IPEEE scope, a number of issues (or sub-issues) have aspects related to internal events (which were covered in the IPE program), as well as aspects related to external events. Only external events aspects are covered in this chapter. Some of these issues relate to seismic events, fires, and HFO events and, therefore, are also discussed in Chapters 2, 3, and 4, respectively. Table 5.1 summarizes this information for the issues (and sub-issues) that are covered within the IPEEE scope.

As shown in Table 5.1, a number of these issues are very closely related. Some issues or sub-issues are identical in scope, but may have different or similar titles. For example, GSI-147, "Fire-Induced Alternate Shutdown/Control Room Panel Interactions" (discussed in Section 5.4.5), is identical to the FRSS issue with the same title[1] (discussed in Section 5.4.9.1.5).

[1] This issue, which NUREG/CR-5088 originally identified as one of the Sandia Fire Risk Scoping Study issues, was later designated as a generic issue and was tracked in the NRC's generic issue program (NUREG-0933).

Table 5.1: Generic safety issues addressed in the IPEEE program

Generic Safety Issue (GSI)	Area[1]	USI/GSI	FRSS	GSI-156	GSI-172	Remark[2]
Shutdown Decay Heat Removal Requirements	S,F	USI A-45				EX
Potential Seismic Interaction Involving the Movable In-Core Mapping System	S	GSI-131				C
Effects of Fire Protection System Actuation on Safety-Related Equipment	S,F	GSI-57	X		X	P
Fire-Induced Alternate Shutdown/Control Room Panel Interaction	F	GSI-147	X			C
Smoke Control and Manual Fire-Fighting Effectiveness	F	GSI-148	X			P
Seismic-fire Interactions	F		X		X	C
Adequacy of Fire Barriers	F		X			C
Effects of Hydrogen Line Ruptures	S,F				X	C
Settlement of Foundations and Buried Equipment	S			X		P
Dam Integrity and Site Flooding	S,HFO			X		C
Seismic Design of Structures, Systems, and Components	S			X		C
Common Cause Failures Related to Human Errors	S,F				X	EX
Non-Safety-Related Control System/Safety-Related Protection System Dependencies	S,F				X	EX
Effects of Flooding and/or Moisture Intrusion on Non-Safety-Related and Safety-Related Equipment	F,HFO				X	EX
Seismically Induced Spatial and Functional Interaction	S				X	C
Seismically Induced Flooding	S				X	C
Seismically Induced Relay Chatter	S				X	C
Evaluation of Earthquake Magnitudes Greater than Safe Shutdown Earthquake	S				X	C
Design for Probable Maximum Precipitation	HFO	GSI-103				C
Site Hydrology and Ability to Withstand Floods	HFO			X		P
Industrial Hazards	HFO			X		C
Tornado Missiles	HFO			X		C
Severe Weather Effects on Structures	HFO			X		C
Design Codes, Criteria, and Load Combinations	S,HFO			X		C
Shutdown Systems and Electrical Instrumentation and Control Features	F			X		EX

[1]S=seismic, F=internal fires, HFO=high winds, floods, and other external events

[2]C=issue covered by IPEEE; EX=only external event-related aspects of issue covered; P=partially covered (refer to specific section of the text for details)

The scope of most of these generic issues is covered in its entirety by the IPEEE program. These issues are noted in the remarks column of Table 5.1 by the letter "C" (i.e., the issue is covered by the IPEEE). As noted above, the scope of some issues includes aspects of both internal and external events. For example, USI A-45, "Shutdown Decay Heat Removal Requirements," includes potential plant vulnerabilities associated with internal event initiators as well as external event initiators. The IPEEE program covers only the external event-related aspects of this issue. (The internal event aspects were covered in the IPE program.) Issues such as this are noted by "EX" (i.e., only the external event-related aspects of the issue are covered) in the remarks column of Table 5.1. The other designator in the remarks column is "P" (i.e., is partially covered in the IPEEE program). The scope of these issues, as defined in NUREG-0933, includes some aspects that go beyond those that are covered by the IPEEE program. For example, GSI-148, "Smoke Control and Manual Fire-Fighting Effectiveness" (discussed in Section 5.4.6), does not cover the effects of potentially damaging mechanisms, such as smoke, on equipment. Data on smoke-induced damage to equipment are sparse and, hence, it was not anticipated that the IPEEE analyses would assess this potentially damaging mechanism. Other parts of GSI-148 are covered by the IPEEE program (see Section 5.4.6). Each of these issues and sub-issues is discussed in more detail in Section 5.4.

As discussed in previous chapters, there were 70 IPEEE submittals; however, the staff prepared only 69 staff evaluation reports because one plant (Haddam Neck) was permanently shut down after providing its IPEEE submittal. Therefore, the discussions and tables in this chapter related to USIs and GSIs (which are addressed in the staff evaluation reports) address only 69 submittals.

Sections 5.2 and 5.3 discuss the process used by licensees and the staff, respectively, in evaluating the USIs and GSIs. This is followed by Section 5.4, which describes each individual issue and sub-issue and presents an overview of their treatment in the IPEEE submittals. Section 5.5 presents a summary and the staff's conclusions.

5.2 Overview of Licensees' Assessment Processes

This section describes the processes that the licensees used to arrive at their conclusions regarding the verification of the USIs and GSIs that they were asked to address within the context of the IPEEE program. In general, the licensees' processes included performing seismic, fire, and HFO walkdowns, which involved USI/GSI aspects related to the individual plant. In the case of seismic walkdowns, the licensees used a seismic review team (SRT) to review documentation of the walkdowns that were conducted and, in some cases, performed additional verification walkdowns.

The licensees also used probabilistic risk assessment (PRA) techniques to examine the dominant accident sequences and their associated initiating events. When these examinations revealed no vulnerability or no particular plant feature with a potentially significant risk contribution, the licensees concluded that the external event aspects of the considered USIs and GSIs were verified. Usually, the licensees also subjected their assessments and conclusions to an independent peer review before submitting the IPEEE study to the NRC.

5.3 USI/GSI Staff Review Evaluation Process

This section discusses the process that the staff used to assess the acceptability of the licensees' conclusions regarding the USIs and GSIs in the IPEEE submittals. The staff's judgement regarding for USI and GSI verification was based on the following criteria.

- The licensee's IPEEE is complete with regard to USI and GSI coverage.
- The licensee's assessment demonstrated an in-depth knowledge of the external event aspects and plant characteristics that are relevant to the issues discussed.
- The licensee's assessment results are reasonable given the design, location, features, and operating history of the plant.

An issue is thus considered verified if the submittal did not identify any potential vulnerabilities associated with its related concerns, or the licensee implemented plant-specific improvements to eliminate or reduce the significance of the identified potential vulnerabilities at the plant. For example, during plant walkdowns, some licensees identified improvements to strengthen equipment anchorages to reduce seismically induced spatial interactions (one of the MSRP sub-issues discussed in Section 5.4.8.2.7). In a few cases, licensees identified improvements related to a generic issue that were planned, but had not been implemented at the time of the IPEEE submittal. Confirmation that "planned" improvements have been made with regard to a generic issue is recommended.

The staff assessed the acceptability of the licensees' conclusions on the basis of information in the IPEEE submittals, which was sometimes supplemented by the licensees' responses to the staff's requests for additional information (RAIs) seeking clarification or supplemental assessments of certain aspects of the submittal.

Furthermore, the staff established an IPEEE Senior Review Board (SRB), which held meetings on a regular basis. The SRB comprised NRC staff and consultants with specialized expertise in the various aspects of external events and PRA. In these meetings, the SRB members provided their perspectives on the IPEEE review findings, and recommended actions on the basis of their technical specialities. In this manner, the SRB provided additional assurance that each review met the IPEEE program objectives.

The IPEEE reviews showed that most of the submittals contain information that addresses most of the GSIs. However, if a submittal did not discuss the issue or sub-issues, and the reviewers determined whether the missing information could cause the licensee to overlook a potential vulnerability at their plant. On the basis of the SRB members' expert judgement and information on similar issues from other IPEEE submittals, RAIs were sent to licensees if a potential vulnerability could have been missed or if information in response to the RAI would be likely to uncover a significant problem with the IPEEE results. However if a licensee's submittal did not address an issue or sub-issue, but did not miss a potential vulnerability, the NRC's staff evaluation report (SER) identified the omission as a "weakness" in the submittal. In such cases, the submittals still meet the intent of Supplement 4 to Generic Letter 88-20, but the GSI may not be "verified" for that plant.

Table 5.2 shows the status of each of the IPEEE-related USI and GSI issues for all of the plants. A "yes" indicates that the particular issue was verified for that plant. A "no" indicates that the staff did not have sufficient information from either the submittal or the responsea to RAIs to determine whether the issue was adequately addressed. An "N/A" means that the issue was not applicable to the given plant. For example, GSI-131, "Potential Seismic Interactions Involving the Movable In-Core Flux Mapping System Used in Westinghouse Plants," only applies to Westinghouse plants. Several issues (e.g., GSI-156, GSI-172, and the FRSS issues) comprise a number of sub-issues. Issues in Table 5.2 that are shown to be "partially" verified indicate that one or more of the sub-issues may not be verified, but the remaining sub-issues are verified.

Table 5.2: IPEEE USI/GSI verification

Plant name	USI A-45	GSI-57	GSI-103	GSI-131	FRSS	GSI-147	GSI-148	GSI-156	GSI-172
Arkansas 1 & 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Beaver Valley 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Beaver Valley 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Braidwood 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Browns Ferry 2 & 3	Yes	Yes	Yes	N/A	Partial	Yes	Partial	Yes	Partial
Brunswick 1 & 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Byron 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Callaway	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Calvert Cliffs 1 & 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Catawba 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Clinton	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Columbia Generating[1]	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Comanche Peak 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Cooper	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Crystal River 3	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Partial
D.C. Cook 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Davis Besse	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Diablo Canyon 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Dresden 2 & 3	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Duane Arnold	Yes	Yes	Yes	N/A	Partial	Yes	Partial	Yes	Yes
Farley 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Partial

[1] Formerly known as Washington Nuclear Project No. 2 (WNP-2).

Table 5.2: IPEEE USI/GSI verification (Continued)

Plant name	USI A-45	GSI-57	GSI-103	GSI-131	FRSS	GSI-147	GSI-148	GSI-156	GSI-172
Fermi 2	Yes	Yes	Yes	N/A	Partial	Yes	Partial	N/A	Yes
Fitzpatrick	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Fort Calhoun	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Ginna	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grand Gulf	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Hatch 1 & 2	Yes	Yes	Yes	N/A	Partial	Partial	Partial	Yes	Partial
Hope Creek	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Indian Point 2	Yes	Yes	Yes	Yes	Partial	Yes	Partial	Yes	Yes
Indian Point 3	Yes	Yes	Yes	Yes	Partial	Yes	Partial	Yes	Yes
Kewaunee	Yes	Yes	Yes	Yes	Partial	Yes	No	Yes	Partial
LaSalle[2]	Yes	No	Partial	N/A	Partial	Yes	No	N/A	Partial
Limerick 1 & 2	Yes	Yes	Yes	N/A	Yes	Yes	Partial	N/A	Partial
Millstone 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Millstone 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Monticello	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
McGuire 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Nine Mile Point 1	Yes	Yes	Yes	N/A	Partial	Yes	Partial	Yes	Yes
Nine Mile Point 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
North Anna 1 & 2	Yes	Yes	Yes	Yes	Yes	Partial	Partial	N/A	Partial
Oconee 1, 2, & 3	Yes	Yes	Yes	N/A	Partial	Yes	Partial	Yes	Yes
Oyster Creek	Yes	Yes	Yes	N/A	Partial	Yes	Partial	Yes	Yes
Palisades	Yes	Yes	Yes	N/A	Yes	Partial	Yes	Yes	Yes
Palo Verde 1, 2, & 3	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes

[2] The licensee relied exclusively upon previously published NRC PRA reports (NUREG/CR-4832, "Analysis of the LaSalle Unit 2 Nuclear Power Plant: Risk Methods Integration and Evaluation Program (RMIEP)," and NUREG/CR-5305, "Integrated Risk Assessment for the LaSalle Unit 2 Nuclear Power Plant: Phenomenology and Risk Uncertainty Evaluation Program (PRUEP)") and provided no additional information related to generic issues. This is evidenced by the lack of verification for any issue outside of those that could be deduced from the RMIEP study.

Table 5.2: IPEEE USI/GSI verification (Continued)

Plant name	USI A-45	GSI-57	GSI-103	GSI-131	FRSS	GSI-147	GSI-148	GSI-156	GSI-172
Peach Bottom 2 & 3	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Perry	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Pilgrim	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Point Beach 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prairie Island 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quad Cities 1 & 2	Yes	Yes	Partial	N/A	Yes	Yes	Partial	Yes	Yes
River Bend	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Robinson 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Salem 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
San Onofre 2 & 3	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Seabrook	Yes	Yes	Yes	Yes	Partial	No	No	N/A	Partial
Sequoyah 1 & 2	Yes	Yes	Partial	Yes	Yes	Yes	Yes	N/A	Yes
Shearon Harris	Yes	Yes	Yes	Yes	Partial	Yes	Partial	N/A	Yes
South Texas 1 & 2	Yes	Yes	N.A.[3]	Yes	Yes	Yes	Yes	N/A	Yes
St. Lucie 1 & 2	Yes	Partial	Yes	N/A	Partial	Yes	Partial	N/A	Partial
Summer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Surry 1 & 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Susquehanna 1 & 2	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	Yes
Three Mile Island 1	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Turkey Point 3 & 4	Yes	Partial	Yes	Yes	Partial	Yes	No	Yes	Partial
Vermont Yankee	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Vogtle 1 & 2	Yes	Yes	Yes	Yes	Partial	Yes	Partial	N/A	Partial
Waterford 3	Yes	Yes	Yes	N/A	Yes	Yes	Partial	N/A	Partial
Watts Bar 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Partial
Wolf Creek	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes

[3] A new PMP evaluation was not required for South Texas because the impact of the new PMP criteria had previously been evaluated as part of the operating license process in 1989, in accordance with GL 89-22, "Potential for Increased Roof Loads and Plant Area Flood Runoff Depth at Licensed Nuclear Power Plants Due to Recent Change in Probable Maximum Precipitation Criteria Developed by the National Weather Service."

(The plant-specific tables in Volume 2 of this report provide additional information showing which sub-issues are or are not verified for each plant.) For those issues that have not been completely verified, the NRC staff will determine if any additional actions or assessments are needed to verify these GSIs. This follow-up will be done separately from the IPEEE program.

The following sections discuss the unverified USIs and GSIs or portions thereof for each plant listed above.

5.4 IPEEE-Related USIs and GSIs

This section discusses the USIs and GSIs that are addressed in the IPEEE submittals. Each specific issue includes the following:

- a description of the issue,
- a discussion of findings and plant modifications that impact this particular issue, and
- additional observations regarding the issue.

5.4.1 USI A-45, "Shutdown Decay Heat Removal (DHR) Requirements"

5.4.1.1 Issue Description

The objective of USI A-45 is to determine whether the decay heat removal function at operating plants is adequate and whether cost-beneficial improvement(s) could be identified. The internal event aspects of USI A-45 were subsumed in the IPE (Generic Letter 88-20); therefore, the external event aspects, including fire-related issues and seismic adequacy of the decay heat removal systems, are included in the IPEEE. Thus, the purpose of the IPEEE related to USI A-45 is to identify any significant and unique seismic and fire vulnerabilities in the decay heat removal function.

5.4.1.2 Findings and Related Plant Modifications

Most licensees explicitly addressed USI A-45 in their IPEEE submittals. Those submittals that did not explicitly mention this issue implicitly addressed USI A-45 by providing adequate information on the potential loss of decay heat removal capability through the evaluation of seismic and fire events, which would ensure adequate decay heat removal under these conditions.

The seismic evaluation of all plants included decay heat removal equipment. Plants that performed a seismic PRA provided a quantitative evaluation of the contribution of potential loss of decay heat removal to the estimated CDF.

The plants that performed seismic margin analyses (SMA) included the equipment that would be used for decay heat removal on their IPEEE safe shutdown equipment list (SSEL). The licensees then performed a fragility analysis of all of the equipment on the SSEL. For licensees that performed an SMA, this analysis resulted in identification of each component's high confidence of low probability of failure (HCLPF) value. Usually, the licensees would state that most or all of the components' HCLPF values were greater than the review-level earthquake (RLE) value (usually 0.3 g except for six plants that had 0.5 g — see Section 2.1.3.2) and would only identify those components that had HCLPF values close to or below the RLE. Those licensees that had HCLPF values below the RLE usually either performed a more detailed evaluation that resulted in removing the components from the SSEL, the revised HCLPF value being higher than the RLE, or citing some plant change that would result in a higher HCLPF value. In some cases, the licensees determined that there was no cost-beneficial modification that would significantly improve the HCLPF value. All plants had HCLPF values for the equipment on the SSEL in excess of the safe shutdown earthquake (SSE).

NUREG-1407 identified 10 plants as "reduced-scope" plants. These plants are located in areas where the seismic challenge is deemed to be significantly reduced, such that the design basis earthquake is an adequate representation of the perceived seismic challenge. For these plants, the RLE was the same as the SSE. Therefore, for reduced-scope plants, demonstrating that the equipment on the SSEL would remain functional at the SSE level and there were no vulnerabilities was sufficient for addressing USI A-45.

Some licensees addressed potential loss of decay heat removal capability in the event of a fire through a fire PRA, a few of which included Level 2. Some plants used the decay heat removal model from their IPE to model postulated fire events as part of their IPEEE. Other plants developed alternative success paths. Typically, these drew on previous work, such as the fire hazard analyses conducted in accordance with Appendix A to 10 CFR Part 50, or compliance with Appendix R to 10 CFR Part 50.

5.4.1.3 Observations

Whether a licensee used an SPRA or an SMA for the seismic IPEEE, the capability of decay heat removal functions is directly included by definition. Thus, any findings encountered in the IPEEE with respect to seismic capability of DHR functions also apply to USI A-45. In other words, for seismic events, USI A-45 perspectives are a subset of the IPEEE perspectives. Consequently, the IPEEE submittals generally reiterated those seismic IPEEE findings pertaining to DHR capability as the basis for the verification of USI A-45.

The NRC concludes that all plants have adequately addressed USI A-45. All plants have identified at least one method of removing decay heat for postulated fire events. While not all plants have an identified margin in excess of the needs for safe shutdown during an SSE (e.g., the reduced-scope plants) the NRC has determined that the IPEEEs have performed an adequate assessment to identify potential vulnerabilities in the decay heat removal systems consistent with the guidance in NUREG-1407, and no vulnerabilities were found.

5.4.2 GSI-57, "Effects of Fire Protection System Actuation on Safety-Related Equipment"

5.4.2.1 Issue Description

GSI-57 addresses the potential that the activation of fire suppression systems, either as part of actual fire-fighting or spuriously, might result in damage to plant systems and components. The analytical results obtained for prioritization of this issue by the NRC identified the following dominant risk contributors as:

- seismically induced fire plus seismically induced suppression diversion, and
- seismically induced actuation of the fire protection system (FPS).

The NRC anticipated that licensees would conduct seismic and fire walkdowns, as described in Section 7.0 of EPRI's Fire-Induced Vulnerability Evaluation (FIVE) methodology. These walkdowns were expected to assess whether (1) an actuated FPS would spray safety-related equipment, and (2) some protective measures, if needed, could be implemented to prevent the safety-related equipment from being sprayed by fire suppressants.

Other potential damage mechanisms, such as smoke and fire suppressant damage (either from fixed systems or manual actions), have not been considered. In general, this is an area where the database on equipment vulnerability is rather sparse. Similarly, analytical methods and tools (such as computer codes) have not generally been evaluated in the context of fire risk assessment. Hence, it is not anticipated that the IPEEE analysis would provide a detailed assessment of smoke- and suppressant-induced damage.

5.4.2.2 Findings and Related Plant Modifications

Some licensees noted that their fire protection system was designed in accordance with the guidelines of Category II/I in safety-related structures and areas (Regulatory Guide 1.29, "Seismic Design Criteria," Revision 3, September 1978, Regulatory Position C.2). This guideline states that wherever a Category II component (e.g., the non-safety-related fire protection system) is installed above a Category I component (i.e., safety-related), no failure mode of the Category II system or component is to adversely impact the Category I system or component. This includes seismic events. Thus, seismically induced failure of the fire protection system could fail the piping, but the failed piping would not adversely impact the performance of the safety-related structures, systems, or components. This includes the potential falling of the failed pipe and the potential release of water from the failed pipe.

Many licensees noted that some, or all, of their water-based fire protection systems required two diverse actions for initiation (pre-action type). One action would be for a smoke detector to open a supply valve in the fire protection system, while the second action is heat from the fire to melt the fusible link in the sprinkler head. For this type of system, the licensees concluded that inadvertent activation of the fire protection system by a seismic event or associated dust was not a problem.

Most licensees performed walkdowns as part of the verification of this generic issue. Typically, these walkdowns reviewed the spatial relationship between the fire protection system and safety-related components. This was particularly applicable to those licensees that had deluge fire protection systems. The safety-related components were reviewed to ensure that postulated failure of the fire protection system under seismic conditions would not adversely affect safety-related equipment from a falling component or from the water released from the fire protection system. The walkdowns also identified the presence of seals in the top of safety-related cabinets to prevent water intrusion and of area drains to remove excess water to prevent flooding. Most floor drainage systems were sized for flooding induced by pipe breaks. Generally, fire protection systems have lower flow rates and would be less likely to flood a compartment. However, some licensees have identified potential drain plugging issues and have revised or developed procedures to periodically inspect the drainage system to reduce the probability of plugging.

The impact of CO_2 or Halon protective system actuation was also reviewed as it relates to potential effects on personnel (e.g., control room operators) and equipment (e.g., operation of the diesel generators) in the area. Usually potential problems from these systems were dismissed as having an insignificant impact on plant safety or were beyond the scope of this generic issue. Data on the effects of smoke and fire suppressants on equipment are limited, and such effects were considered to be beyond the scope of the IPEEE program.

A few licensees discussed the potential effects of corrosion, buildup of soot, or other combustion products on equipment operability. Those that discussed this aspect stated that potential damage would occur over a much longer period of time than required to establish cold shutdown. Corrective maintenance would resolve any long-term problem that might be caused by these mechanisms. The majority of the submittals did not discuss the impact of combustion products on equipment operability or stated that there was insufficient information to address the issue.

A number of licensees stated that operators in their plants receive training on the use of the abnormal operating procedures for fire situations. Some of the licensees stated that training included live fire or live smoke conditions. Frequently, the licensees stated that timing records are kept for the fire brigade training exercises. Some licensees used this information to demonstrate that the manual fire-fighting times used in the IPEEE are conservative.

The licensees concluded that the impact of seismically induced activation of fire suppression systems, suppressant diversion, and adverse effects on safety-related components was negligibly small.

5.4.2.3 Observations

The information provided in the submittals is usually qualitative and provides little detail. Table 5.1 of Volume 2 of this report lists the plants and whether they addressed the two items in the generic issue. All but four of the plants have provided adequate information to verify this generic issue. One plant (LaSalle) provided no information, and three provided only partial information. Review of the submittals indicates that the licensees generally have an appreciation for the potential impacts of fire systems on safety-related components and systems.

5.4.3 GSI-103, "Design for Probable Maximum Precipitation"

5.4.3.1 Issue Description

The latest probable maximum precipitation (PMP) criteria published by the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) may identify higher rainfall intensities over shorter time intervals and smaller areas than have previously been considered. This could result in higher site flooding levels and greater roof ponding loads than have been used in previous design bases. The IPEEE program includes an assessment of the effects of applying these new PMP criteria to each plant in terms of potential severe accident vulnerabilities associated with onsite flooding and roof ponding. To provide the revised PMP estimates, licensees typically used the information in the NOAA Hydrometeorological Report (HMR) 51, "Probable Maximum Precipitation Estimate, United States East of 105th Meridian," HMR 52, "Application of Probable Maximum Precipitation Estimates – United States East of the 105th Meridian," and HMR 53, "Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, United States East of the 105th Meridian."

5.4.3.2 Findings and Related Plant Modifications

Typically, licensees determinee the revised PMP rate and evaluated the ability of the roofs to withstand the new accumulation of water. Table 5.2 of Volume 2 of this report shows the PMP information provided in the submittals. Usually, the roofs can withstand the additional loads because the excess rainfall overflows the roof parapets. In some cases, licenses installed scuppers in the parapets to accommodate additional precipitation. In many situations, licensees credited roof drains for water removal. Such licensees frequently identified a new or existing procedure to periodically inspect the roof drainage system for potential blockage. In the unusual case that a structure was found to be unable to withstand the new loadings, the licensee evaluated the impact of roof failure and water intrusion into the building. No plant vulnerabilities related to this issue were identified in the IPEEE submittals.

Another PMP-related consideration involves its effect on nearby rivers and streams, and the resulting potential for failures of dams and levies. The submittals provided different levels of detail. Some submittals provided a short qualitative narrative. Other submittals provided significant detail. The latter showed that the licensee considered the entire drainage area into a river (or other body of water), and evaluated the impact of this increased water flow on site water levels and on dams and levies. Frequently, licensees consulted with other organizations (e.g., the U.S. Army Corps of Engineers). In some cases, licensees identified static water levels. However, in most cases where detailed information was provided, the licensees also considered wave runup and wind effects to determine the maximum water level at the site. The licensees then compared this water level to the flood protection elevation provided to safety-related structures, systems, and components. Table 5.2 of Volume 2 of this report shows the external flooding elevations and flood-protected elevations provided in the submittals. When licensees identified the potential for flooding of a structure, the licensee reviewed the potential effects of the flooding and either determined that the potential flooding would not adversely affect the plant, or made plant changes including installation of seals, procedures for timely plant shutdown, or procedures to prevent flooding (e.g., installation of sand bags around doorways). Table 5.3 of Volume 2 of this report lists the improvements identified in the submittal for each plant. In one case, the service water systems and a train of the fire protection system could be lost. In this case, the licensee identified actions that could be taken in a timely manner to prevent the total loss of service water.

The last PMP consideration relates to local intense PMP. This issue addresses the potential that site drainage might not adequately remove very intense local precipitation at the site. The licensee usually addressed this by reviewing site elevations and drainage capabilities. Either the resulting water level at the safety-related structures was bounded by the flood water elevation (most frequent finding) or the licensee evaluated the potential in-leakage. The licensee found that (1) this potential in-leakage would result in insignificant water accumulation; (2) it would result in significant water accumulation, but the water level would remain below the elevation of safety-related components; or (3) the potentially affected components would perform their intended function in a submerged condition (least frequent finding). Thus, all licensees concluded that local intense PMP was not a problem.

Most licensees included a confirmatory plant outdoor walkdown to identify building doors and penetrations that might be vulnerable to moisture intrusion. These walkdowns also involved examining of the roof drain systems and plant site drainage. Occasionally, these walkdowns identified weaknesses, and the licensee made some plant change. For example, recognizing the need for the roof drainage system to perform its intended function, one licensee instituted a surveillance procedure to periodically inspect the drains for obstructions.

5.4.3.3 Observations

All but three plants verified all aspects of GSI-103. As shown in Table 5.3, these three plants verified some, but not all, parts of this issue. Two plants neglected to address the issues of roof ponding and external flooding from the revised PMP-induced flooding, and one plant did not address site drainage.

Table 5.3: Unverified areas related to GSI-103

Plant	Revised PMP data	Roof ponding	Site drainage	External flooding*
LaSalle	Not Verified	Verified	Not Verified	Illinois River
Quad Cities 1 & 2	Not Verified	Verified	Not Verified	PMP
Sequoyah 1 & 2	Verified	Not Verified	Verified	Verified
* Source of external flooding that was not verified (i.e., from dam or pond failures) or river flooding as the result of the revised PMP				

One plant (Salem) installed new penetration seals between the service and auxiliary buildings. These new penetration seals significantly reduced the core damage frequency from external floods from approximately 1E-4/ry to 1E-7/ry.

For a few plants, the revised PMP is less than the design basis PMP; nonetheless, the overall conclusion is that the original design and construction of the plants included sufficient margin to allow variations of up to two to three times the original design basis PMP without adversely impacting safe operation of the plant.

5.4.4 GSI-131, "Potential Seismic Interaction Involving the Movable In-Core Flux Mapping System Used in Westinghouse Plants"

5.4.4.1 Issue Description

This issued was identified because portions of the in-core flux mapping (ICFM) system in Westinghouse plants are located directly above the seal table, and may not have been seismically analyzed. Failure of this equipment during a seismic event could potentially result in multiple failures at the seal table and could produce a small-break LOCA (SBLOCA) as a result of instrument tube failure(s). The potential interaction between the seal table and non-seismic Category I systems associated with the movable ICFM system can be identified during the seismic IPEEE walkdown. This issue may be dealt with in the following ways:

- demonstrate that the issue is not applicable to the site, or
- demonstrate that the restraints provide adequate capacity to withstand seismic forces, or
- document and implement administrative controls that preclude unrestrained mobile cart motion.

5.4.4.2 Findings and Related Plant Improvements

Licensees performed walkdowns to verify that previous modifications to their ICFM system were adequate, or to identify potential interactions between the seal table and the ICFM.

Table 2.13 of Volume 2 of this report summarizes the characteristics of the ICFM system for Westinghouse plants. It identifies previous upgrades for each plant and summarizes IPEEE findings and related plant improvements. The improvements ranged from procedures to restrain a chain from falling to installation of angle irons welded to the seal table to bolt the transfer table in place when not in use.

5.4.4.3 Observations

GSI-131 applies only to Westinghouse plants that have a movable ICFM system (see Table 2.13 of Volume 2). For 39 of the 69 plants, GSI-131 is not relevant. For 3 of the 30 Westinghouse plants (Kewaunee, Point Beach 1 and 2), the issue is only partially relevant due to an immobile configuration of the flux mapping cart. Of the 30 plants affected by this generic issue, 19 (~63%) had already verified the issue and completed the modifications that were needed to ensure the that Category II ICFM equipment would not adversely impact the Category I seal table. This was verified by walkdowns and reviewed by a seismic review team. Six plants did not identify any evaluation of this issue before the IPEEE. As part of the IPEEE review, these six plants determined that the as-found condition of the ICFM and seal table was adequate. Many of the plants made some modification to their procedures to provide increased assurance that the ICFM would be left in the appropriate configuration when it is not in use. Table 2.13 of Volume 2 of this report lists this information by individual plant.

In some cases, the licensees undertook a walkdown to verify the installation of a previous improvement as part of the seismic IPEEE. Some plants implemented hardware improvements related to GSI-131 by either replacing the flux mapping system cart hold down bolts or installing stiffener and anchor assemblies for the mapping carts. A few submittals (at least 13 of 30) indicated that the licensees evaluated the capability of the ICFM system for RLE loads. In one case (Kewaunee), the licensee implemented an administrative procedure to help eliminate the potential for an interaction hazard involving an overhead chain hoist. In another submittal (North Anna), the existing configuration of the moveable flux mapping system was found to be adequate, provided that operators reinstalled bolts connecting the cart frame to its supporting beams whenever the cart was moved into position above the seal table. Overall, all 30 plants for which this issue is applicable verified this generic issue.

5.4.5 GSI-147, "Fire-Induced Alternate Shutdown and Control Room Panel Interactions"

5.4.5.1 Issue Description

The issue of control systems interactions is primarily associated with the potential that a fire in the plant (e.g., in the main control room (MCR)) might lead to potential control system vulnerabilities. Given a fire in the plant, the likely control systems interactions are between the control room, the remote shutdown panel, and shutdown systems. The guidance for performing such an assessment is provided in NUREG/CR-5088, "Fire Risk Scoping Study." The following specific areas should be addressed in the IPEEE fire analysis.

- *Electrical independence of the remote shutdown control systems.* The primary concern for control systems interactions occurs at plants that do not provide independent, remote shutdown control systems. The licensees' processes to (a) verify electrical independence and (b) evaluate the level of indication and control of remote shutdown control and monitoring circuits should be reviewed.

- *Loss of control equipment or power before transfer.* The licensees' processes for evaluating the loss of control power for certain control circuits as a result of hot shorts or blown fuses before transferring control to remote shutdown locations should be assessed.

- *Spurious actuation of components leading to component damage, a loss-of-coolant accident (LOCA), or an interfacing systems LOCA.* The licensees' processes for evaluating the spurious actuation of one or more safety-related or safe shutdown-related components as a result of fire-induced cable faults, hot shorts, or component failures leading to component damage, LOCA, or interfacing system LOCAs before taking control from the remote shutdown panel should be assessed. This should also include assessment of the spurious starting and running of pumps, as well as the spurious repositioning of valves.

- *Total loss of system function.* The licensees' processes for evaluating total loss of system function as the result of fire-induced redundant component failure or electrical distribution system (power source) failure should be assessed.

5.4.5.2 Findings and Related Plant Modifications

All but four[4] of the licensees provided adequate information in their IPEEE submittals to verify GSI-147. Table 5.4 of Volume 2 of this report identifies the unique features at specific plants and the areas where adequate information was not provided to verify appropriate implementation of GSI-147.

Many plants relied, in part, on compliance with the requirements of Appendix R to 10 CFR Part 50, or the counterpart guidelines in NUREG-0800, "Standard Review Plan," Section 9.5.1, "Fire Protection Program," and related Branch Technical Positions. As part of the IPEEE review related to fire events and as part of the Sandia Fire Risk Scoping Study, the licensee verified that the plants have the ability to transfer adequate control from the control room to alternate locations to achieve plant safe shutdown conditions (i.e., the alternate location is electrically independent of the control room). The IPEEE submittals indicated that control of any errant equipment would be regained once control was transferred from the control room to the alternate shutdown locations. The licensees stated that no unrecoverable effects from errant equipment would be sustained until control was regained. Once the transfer is accomplished from the control room, the area with the fire is independent from the systems that would be used to control the plant, thereby precluding the total loss of system function for those systems. The Appendix R reviews considered spurious actuation of components, one at a time. As part of the fire IPEEE review, some licensees considered multiple hot shorts, including, in one case (Cooper), the concurrent, independent, spontaneous, and spurious hot short powering of each of the six automatic depressurization system valves. Spurious actuation reviews generally included power cables and signal (or instrumentation) cables. Generally, the potential loss of power to equipment was addressed by feeding the alternate shutdown equipment through a separate, independent breaker or fuse. This alternate feed line was engaged as the control was transferred from the control room.

[4] The four plants that did not provide sufficient information to verify GSI-147 are Hatch, North Anna, Palisades, and Seabrook. The first three plants provided adequate information for three of the four aspects of this issue described in Section 5.4.5.2. The fourth plant, Seabrook, only mentioned in the submittal that control systems interactions were treated in the fire area screening and detailed plant response evaluation. However, the submittal did not address any of the four specific areas. Although the staff could not conclude that this issue was verified for Seabrook, the licensee did perform a quality fire analysis and analyzed control room fire scenarios in detail. Overall, the staff felt that the licensee's IPEEE process was capable of identifying the most likely severe accidents and severe accident vulnerabilities and, therefore, the Seabrook IPEEE met the intent of the IPEEE program. However, the staff's SER noted a weakness in the IPEEE in that GSI-147 was not considered verified for that plant.

Only one plant (Surry) identified any plant modifications specifically related to this issue. In this case, Surry modified some circuits to ensure that the diesel generators and the alternate shutdown panel could be isolated from the control room and to reduce the likelihood of spurious power operated relief valve actuations.

5.4.5.3 Observations

The information in the IPEEE submittals provided a wide range of information on this topic. Some submittals provided sparse information (e.g., "generally immune to the effects of control system interactions" and using the FIVE guidance), while other submittals provided very specific information (e.g., being necessary to perform one or more actions at 14 alternate shutdown panels). The plants' capabilities also varied from having a black-start combustion turbine generator set with dedicated components to plants that use one electrical division of the normal plant equipment with power and control isolation from the control room. Most plants with safe shutdown facilities[5] also require or preferentially desire some operator action(s) or equipment operation outside of the safe shutdown facility in the event of control room abandonment. The effectiveness of the previous work associated with Appendix R (and its counterpart in the Standard Review Plan) is evidenced by only one plant finding the need to make a plant modification related to its alternate shutdown capability. Overall, the staff found that 94% of all plants provided adequate information to verify this generic issue.

It should be noted that the IPEEE program was not intended to enhance or go beyond the current state-of-the-art. This includes potential electric circuit interactions as the result of postulated fires. For the most part, licensees satisfactorily performed the review of their plants in accordance with the guidance in the generic issue and the state of circuit interaction knowledge at the time of the IPEEE submittals. Recently, the NRC and industry initiated further investigations to determine the likelihood of the different potential fire-induced cable failure modes (circuit interactions). This ongoing investigation is aimed at providing an improved basis for the treatment of circuit interactions and indicates that there is a potential for additional cable interactions that may need to be considered that are beyond those evaluated as part of this generic issue and the IPEEE program. However, this investigation is not complete at this time. Therefore, with the possible exception of the four plants mentioned above, the staff considers GSI-147 to be verified, while recognizing that, at some future date, some related further consideration may be necessary.

5.4.6 GSI 148, "Smoke Control and Manual Fire-Fighting Effectiveness"

5.4.6.1 Issue Description

Smoke control and manual fire-fighting effectiveness are associated with the concern that a potential exists for the buildup of smoke to hamper the efforts of the fire brigade to extinguish fires in a timely manner before damage can occur to plant systems and components important to safety. (It should be recognized that the brigade response time is not equal to the extinguishment time.) Any risk-significant fire will generate significant amounts of smoke. Smoke can impact plant risk in several ways.

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[5] A safe shutdown facility is an independent, dedicated method of providing safe shutdown. Typically, safe shutdown facilities include an independent, dedicated, black-start power source, pump(s), water supply, and instrumentation and controls that are located outside of the normal plant facility buildings. Generally, only piping, isolation valves, and level instrumentation are located within normal plant facility buildings and are used by the safe shutdown facility.

- Smoke can reduce manual fire-fighting effectiveness (e.g., by causing access problems to the affected fire zone or by causing difficulties in actually locating the fire within the zone), cause misdirected suppression efforts, and subsequently damage equipment that is not directly involved in the fire.

- Smoke can damage or degrade electronic equipment thereby resulting in functional loss or spurious response. However, very little experimental data is available with regard to equipment response in smoke environments and the methodology for including smoke in PRAs has not been adequately developed. Hence, the IPEEE analysis was not expected to provide an assessment of the effect of smoke on equipment.

- Smoke can hamper an operator's ability to safely shutdown the plant by causing evacuation of control centers and subsequent reliance on alternate shutdown capability.

- Smoke can initiate automatic fire protection systems in areas away from the fire, thereby potentially damaging safety-related systems or components. This aspect is separately addressed in GSI-57, "Effects of Fire Protection System Actuation on Safety-Related Equipment" (see Section 5.4.2).

5.4.6.2 Findings and Related Plant Modifications

Of the IPEEE submittals, only 19 credited manual fire-fighting actions. In addition, 25 submittals identified manual fire-fighting for only select areas (e.g., the control room) or select accident scenarios. Normally, not crediting manual fire-fighting is a conservative approach to the assessment of fire growth and direct fire damage timing issues because this assumes that all equipment within a fire zone is destroyed. Usually, those submittals that credited manual fire-fighting also considered the following:

- delays in manual actuation of suppression systems (e.g., while verifying the existence of a fire),
- delays in locating the fire, once the fire brigade has arrived,
- time required to extinguish or substantially control a fire, once fire-fighting has begun, and
- fire brigade training.

Two of the submittals that credited manual fire-fighting actions did not discuss fire brigade training, fire-fighting equipment, or timing.

Although not taking credit for manual fire-fighting actions in the licensee's analysis is conservative from a PRA standpoint, submittals that did not credit manual fire-fighting actions may not have considered the following potential effects of manual suppression:

- potential damaging effects of misdirected fire suppressants (e.g., to adjacent safety-related equipment), and
- barriers breeched by fire-fighting personnel (e.g., leading to the spread of smoke, fire, or both to adjacent fire areas).

Not considering the potential effects of misdirected suppression was deemed to be a shortcoming in the IPEEE submittals that took some credit for manual fire-fighting. Not considering the potential adverse effects of breaching fire barriers was also deemed to be a weakness. However, even in cases for which the licensees took no credit in the IPEEEs for manual fire-fighting the submittals provides information related to fire brigade training, drills, record keeping, and timing, consistent with the guidance in EPRI's FIVE methodology. In some cases, the information was very detailed. Several submittals identified that training exercises were carried out under live fire or live smoke conditions. In one case (Grand Gulf), the licensee simulated the actual plant configuration for the fire exercise with live fire and changed the configuration for each drill. Another submittal (Salem) identified that there is a dedicated fire department for the plant.

Some licensees discussed the potential for the effects of fire to adversely affect equipment that is not directly involved with the fire. This includes potential effects (corrosion or buildup of soot and/or other combustion products) that occur over a much longer period of time than that required to establish cold shutdown. In such cases, the submittal identified that corrective maintenance would resolve any induced equipment problem. The remaining submittals did not discuss the impact of combustion products on equipment operability. Some submittals (e.g., Browns Ferry and Farley) limited their discussion of mitigating the effects of smoke to the use of self-contained breathing apparatus and portable ventilation equipment. Two submittals (Grand Gulf and Waterford 3) specifically identified that fire brigade members were educated on the toxic and corrosive characteristics of combustion products. It should be noted, however, that there is little information about this topic in the currently available literature.

The IPEEE submittals did not identify any plant modifications or procedural changes associated with this generic issue. Table 5.5 of Volume 2 of this report provides plant-specific information found in the SERs and TERs related to this generic safety issue.

5.4.6.3 Observations

Manual fire-fighting activities were credited in 19 submittals, were credited for only select fire areas or fire scenarios in 25 submittals, and were explicitly not credited in 13 submittals. This generic issue was verified for 49 plants (71%), partially verified for 17 plants (25%), and not verified for 3 plants (4%).

5.4.7 GSI-156, "Systematic Evaluation Program"

5.4.7.1 Issue Description

The Systematic Evaluation Program (SEP) was developed to review plants that were licensed before the 1975 edition of the Standard Review Plan (SRP) was issued (i.e., were licensed without explicitly addressing the information in the 1975 SRP). Of the 70 submittals, 31 are for plants that are in the SEP program. (The remaining 29 submittals are for plants that are not in the SEP program.) Nine SEP issues were reviewed as part of the IPEEE program. Each of these issues is discussed in the following sections.

5.4.7.1.1 Site Hydrology and Ability to Withstand Floods

The objective of this issue is to identify the site hydrologic characteristics to ensure the capability of safety-related structures to withstand flooding, to ensure adequate cooling water supply, and in-service inspection of water-control structures. This issue involves assessing the following:

- hydrologic conditions - to ensure that plant design reflects appropriate hydrologic conditions,
- flooding potential and protection - to ensure that the plant is adequately protected against floods, and
- ultimate heat sink - to ensure an appropriate supply of cooling water during normal and emergency shutdown conditions.

Issues related to in-service inspection of water-control structures constitue compliance issues that are not part of the IPEEE program.

5.4.7.1.2 Industrial Hazards

The objective of this issue is to ensure that the integrity of safety-related structures, systems, and components would not be jeopardized as a result of accident hazards from nearby facilities. Such hazards include shock waves from nearby explosions, releases of hazardous gases, or chemicals that result in fires or explosions, aircraft impacts, and missiles resulting from nearby explosions.

5.4.7.1.3 Tornado Missiles

The objective of this issue is to ensure that plants that were constructed before 1972 (SEP plants) are adequately protected against tornadoes. Safety-related structures, systems, and components need to be able to withstand the impact of an appropriate spectrum of postulated tornado-generated missiles.

5.4.7.1.4 Severe Weather Effects on Structures

The objective of this issue is to ensure that safety-related structures, systems, and components are designed to function under all severe weather conditions to which they may be exposed. Meteorological phenomena to be considered include straight wind loads, tornadoes, snow and ice loads, and other phenomena that are deemed to be significant for a particular site.

5.4.7.1.5 Design Codes, Criteria, and Load Combinations

The objective of this issue is to ensure that structures that are important to safety should be designed, fabricated, erected, and tested to quality standards that are commensurate with their safety function. All structures that are classified as Seismic Category I are required to withstand the appropriate design conditions without impairment of structural integrity or reduction in the performance of the required safety functions. Due to the evolutionary nature of design codes and standards, operating plants may have been designed to codes and criteria that differ from those that are currently used in evaluating new plants. Therefore, the review is to ensure that Category I structures will withstand the appropriate design conditions (i.e., against seismic events, high winds, and floods) without impairment of structural integrity or reduction in the performance of required safety functions.

5.4.7.1.6 Dam Integrity and Site Flooding

The objective of this issue is to ensure the ability of a dam to prevent site flooding and ensure a cooling water supply. The safety functions normally include remaining stable under all conditions of reservoir operation, controlling seepage to prevent excessive uplifting water pressures or erosion of soil materials, and providing sufficient freeboard and outlet capacity to prevent overtopping. Therefore, the review is to ensure that adequate safety margins are available under all loading conditions, and uncontrolled releases of retained water are prevented.

The seismic portion of the IPEEE address the concern regarding site flooding resulting from seismic failure of an upstream dam and loss of the ultimate heat sink caused by the seismically induced failure of a downstream dam.

5.4.7.1.7 Settlement of Foundations and Buried Equipment

The objective of this SEP issue is to ensure that safety-related structures, systems, and components are adequately protected against excessive settlement. The scope of this issue includes reviewing subsurface materials and foundations in order to assess the potential static and seismically induced settlement of all safety-related structures and buried equipment. Excessive settlement or collapse of foundations could result in failures of structures, interconnecting piping, or control systems, such that the capability to safely shut down the plant or mitigate the consequences of an accident could be compromised. This issue, which primarily applies to soil sites, involves two specific concerns, namely the (1) potential impact of static settlements of foundations and buried equipment where the soil might not have been properly prepared, and (2) potential seismically induced settlement and soil liquefaction following a postulated seismic event. The potential impact of static settlements of foundations and buried equipment is not believed to pose any significant safety concern and is not included in the IPEEE program.

5.4.7.1.8 Seismic Design of the Structures, Systems, and Components

The objective of this SEP issue is to review and evaluate the original seismic design of safety-related structures, systems, and components, to ensure the capability of the plant to withstand the effects of a safe shutdown earthquake (SSE).

5.4.7.1.9 Shutdown Systems and Electrical Instrumentation and Control Features

With regard to shutdown systems, this issue addresses the capacity of plants to ensure reliable shutdown using safety-grade equipment. The electrical instrumentation and control issue addresses the functional capabilities of electrical instrumentation and control features of systems that are required for safe shutdown, including support systems. These systems should be designed, fabricated, installed, and tested to quality standards and remain functional following external events.

In the IPEEE, licensees were requested to address USI A-45, "Shutdown Decay Heat Removal (DHR) Requirements" (refer to Section 5.4.1 of this report), and to identify potential vulnerabilities associated with DHR systems following the occurrence of external events. The verification of USI A-45 addresses this SEP issue.

5.4.7.2 Findings and Related Plant Improvements

As shown in Table 5.6 of Volume 2 of this report, all of the SEP plants have provided sufficient information in their IPEEE submittals to verify all of the GSI-156 issues. The IPEEE submittals did not explicitly identify any plant modifications or improvements related to this generic safety issue. However, some plants made modifications related to HFO external events (e.g., for protection from tornado-generated missiles and floods) that overlap some of the SEP areas.

By virtue of the licensees having an acceptable IPEEE with regard to external flooding, the site-specific sub-issues related to site hydrology and ability to withstand floods, severe weather effects on structures (water related), and dam integrity and site flooding have been satisfactorily verified. By virtue of the licensees having an acceptable IPEEE with regard to seismic events, the sub-issues related to design codes, criteria, and load combinations; settlement of foundations and buried equipment; and seismic design of structures, systems, and components have been satisfactorily verified. By virtue of the licensee having an acceptable IPEEE with regard to HFO events, the site-specific sub-issues related to industrial hazards, tornado-generated missiles, and severe weather effects on structures (wind related) have been satisfactorily verified. By virtue of the licensee having an acceptable IPEEE with regard to USI A-45, "Shutdown Decay Heat Removal Requirements," the sub-issue related to shutdown systems and electrical instrumentation and control functions has been satisfactorily verified.

5.4.7.3 Observations

Even though the SEP issues were not explicitly identified in Generic Letter 88-20 or NUREG-1407, the NRC has determined that licensees for all of the 31 SEP plants performed an adequate assessment to identify vulnerabilities related to the 9 SEP issues discussed above, and these issues are considered verified.

5.4.8 GSI-172, "Multiple System Response Program"

5.4.8.1 Issue Description

GSI-172, "Multiple System Response Program" (MSRP), addresses concerns raised by the Advisory Committee on Reactor Safeguards (ACRS) regarding safety issues that might exist and might not be addressed by the NRC's existing generic safety issues. Each of the 11 MSRP issues reviewed as part of the IPEEE program are discussed in the following sections.

5.4.8.1.1 Effects of Fire Suppression System Actuation on Non-Safety-Related and Safety-Related Equipment

Fire suppression system actuation can have an adverse effect on safety-related components either through direct contact with suppression agents or through indirect interaction with non-safety-related components. This issue is addressed by the verification of GSI-57, which is discussed in Section 5.4.2 of this report.

5.4.8.1.2 Seismically Induced Fire Suppression System Actuation

Seismic events can potentially cause multiple fire suppression system actuations which, in turn, may cause failures of redundant trains of safety-related systems. Analyses currently required by fire protection regulations generally only examine inadvertent actuations of fire suppression systems as a single, independent event, whereas a seismic event could cause multiple actuations of fire suppression systems in various areas of the plant. This issue is addressed by the verification of GSI-57, which is discussed in Section 5.4.2 of this report.

5.4.8.1.3 Seismically Induced Fires

Seismically induced fires have the potential to cause multiple failures of safety-related systems. The occurrence of a seismic event could create fires in multiple locations, thereby simultaneously degrading fire suppression capability and, therefore, preventing mitigation of fire damage to multiple safety-related systems. This issue is addressed by the verification of the Fire Risk Scoping Study (FRSS) issue entitled "Seismic-Fire Interactions," discussed in Section 5.4.9.1.1 of this report.

5.4.8.1.4 Effects of Hydrogen Line Ruptures

Nuclear power plans use hydrogen in electrical generators to reduce windage losses and as a heat transfer agent. Hydrogen is also used as a cover gas in some tanks (e.g., volume control tanks). Leaks or breaks in hydrogen supply piping could result in the accumulation of a combustible mixture of air and hydrogen in vital areas, resulting in a fire and/or explosion that could damage vital safety-related systems in the plants.

5.4.8.1.5 Non-Safety-Related Control System/Safety-Related Protection System Dependencies

Multiple failures in non-safety-related control systems may adversely impact safety-related protection systems as a result of potential unrecognized dependencies between control and protection systems. The concern is that plant-specific implementation of the regulations regarding separation and independence of control and protection systems may be inadequate. The licensees' IPE process should provide a framework for systematic evaluation of interdependencies between safety-related and non-safety-related systems and identify potential sources of vulnerabilities. The dependencies between safety-related and non-safety-related systems resulting from external events (i.e., concerns related to spatial/functional interactions) are addressed in GSI-147 (Section 5.4.5), the fire risk scoping study (Section 5.4.9.1.5), and the MSRP issue on seismically induced spatial and functional interactions (Section 5.4.8.1.7 of this report).

5.4.8.1.6 Effects of Flooding and/or Moisture Intrusion on Non-Safety-Related and Safety-Related Equipment

Flooding and water intrusion events can affect safety-related equipment either directly or indirectly through flooding or moisture intrusion of multiple trains of non-safety-related equipment. This type of event can result from external flooding events, tank and pipe ruptures, actuation of fire suppression systems, or backflow through part of the plant drainage system. The IPE process addressed the concerns of moisture intrusion and internal flooding (i.e., tank and pipe ruptures or backflow through part of the plant drainage system). The IPEEE program addressed the external flooding-related aspects of this issue (discussed in Section 4.3 of this report) and the potential effects of actuation of the fire suppression system on safety-related equipment (see Section 5.4.2).

5.4.8.1.7 Seismically Induced Spatial/Functional Interactions

Seismic events have the potential to cause multiple failures of safety-related systems through spatial and functional interactions. Some particular sources of concern include ruptures in small piping that may disable essential plant shutdown systems; direct impact of non-seismically qualified structures, systems, and components that may cause small piping failures; seismic functional interactions of control and safety-related protection systems via multiple non-safety-related control system failures; and indirect impacts, such as dust generation, that disable essential plant shutdown systems.

5.4.8.1.8 Seismically Induced Flooding

Seismically induced flooding events can potentially cause multiple failures of safety-related systems. The rupture of small piping could provide flood sources that could potentially affect multiple safety-related components simultaneously. Similarly, non-seismically qualified tanks are a potential flood source of concern.

5.4.8.1.9 Seismically Induced Relay Chatter

Essential relays must operate during and after an earthquake, and must meet one of the following conditions:

- remain functional (i.e., without occurrence of contact chattering),
- be seismically qualified, or
- be chatter acceptable.

It is possible that contact chatter of relays not required to operate during seismic events may produce some unanalyzed faulting mode that may affect the operability of equipment required to mitigate the event. These would be defined as "low-ruggedness" or "bad actor" relays.

5.4.8.1.10 IPEEE-Related Aspects of Common Cause Failures Related to Human Errors

Common cause failures resulting from human errors include operator acts of commission or omission that could be initiating events or could affect redundant safety-related trains needed to mitigate the events. Other human errors that could initiate common cause failures include manufacturing errors in components that affect redundant trains, and installation, maintenance, or testing errors that are repeated on redundant trains. In the IPEEE, licensees were requested to address only the human errors involving operator recovery actions following the occurrence of external events.

5.4.8.1.11 Evaluation of Earthquake Magnitudes Greater Than Safe Shutdown Earthquake

This issue was identified to address concerns that adequate margin may not have been included in the design of some safety-related equipment. As part of the IPEEE, all licensees were expected to identify potential seismic vulnerabilities or assess the seismic capacities of their plants by performing either a seismic PRA or a seismic margins assessment (SMA). The licensees' evaluation for potential vulnerabilities (or unusually low plant seismic capacity) to seismic events addresses this issue.

5.4.8.2 Findings and Related Plant Improvements

Of the 69 submittals, 56 provided sufficient information to adequately verify all 11 MSRP sub-issues. The remaining 13 IPEEE submittals did not provide adequate information to verify one or more of these MSRP issues. Of those 13 submittals, 5 contained information to only partially verify one or more of these issues. Table 5.4 identifies which portion(s) remain(s) unverified for these five plants. Figure 5.1 shows the distribution of unverified or partially unverified sub-issues by plant. As this figure shows, most plants (56) have verified all of the GSI-172 issues. This figure also shows that only one plant (LaSalle) did not provide adequate information to verify 7 of the 11 issues, and one plant (St. Lucie) had 5 issues that remain unverified. Figure 5.2 shows the distribution of unverified or partially unverified sub-issues by sub-issue. As this figure shows, the most frequent unverified issue deals with human error-induced common cause failures related to external event initiators (approximately 10% of the plants). The next two most frequent unverified issues relate to evaluation of seismically induced flooding and potential hydrogen line ruptures (each approximately 7% of the plants).

None of the submittals explicitly identified that any plant modifications or improvements were directly related to the MSRP issues. However, improvements made in conjunction with other external events (e.g., flooding) would also produce a benefit relative to the MSRP issues.

Table 5.4: Partially verified GSI-172 sub-issues by plant

Plant	Aspect verified	Aspect not verified
Hatch 1 & 2	Seismically induced fires for SSEL electrical cabinets	Seismically induced fires for non-SSEL electrical cabinets
	Hydrogen tank ruptures	Hydrogen line ruptures
	Safety/non-safety system interactions	Hot shorts
LaSalle	Effects of flooding on equipment	Effects of moisture intrusion on equipment
Limerick 1 & 2	Flooding from all external sources	Seismically induced internal flooding
	Common cause human factors related to fire events	Common cause human factors related to seismic events
North Anna	Common cause human factors related to fire events	Common cause human factors related to seismic events
Seabrook	Seismically induced fires from equipment interactions	Seismically induced fires from electrical cabinet interactions
	Hydrogen tank ruptures	Hydrogen line ruptures

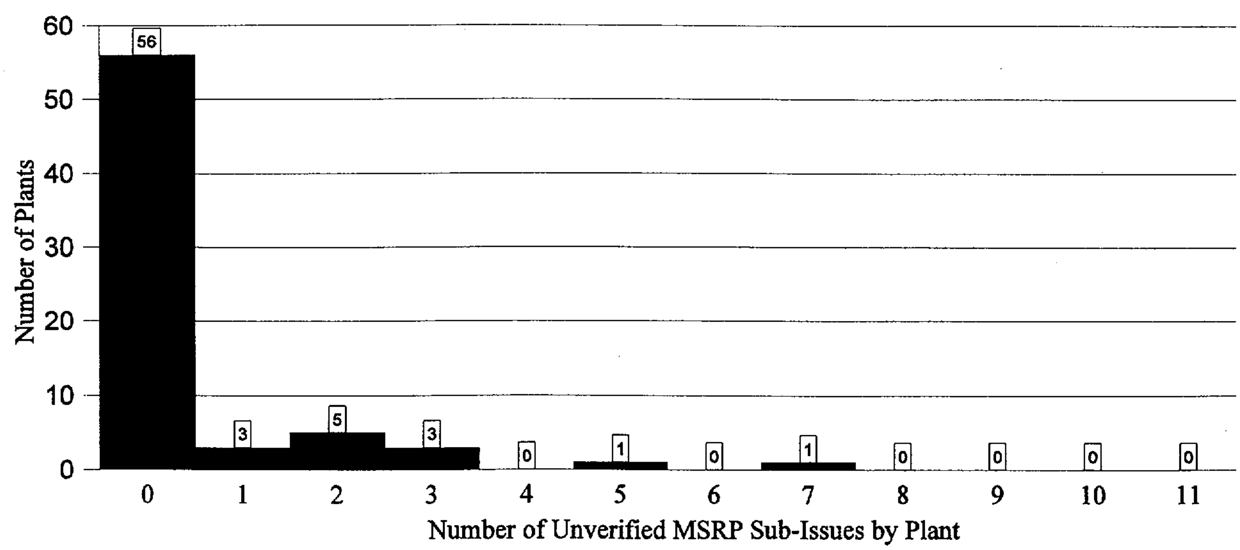

Figure 5.1 Number of unverified GSI-172 issues by plant

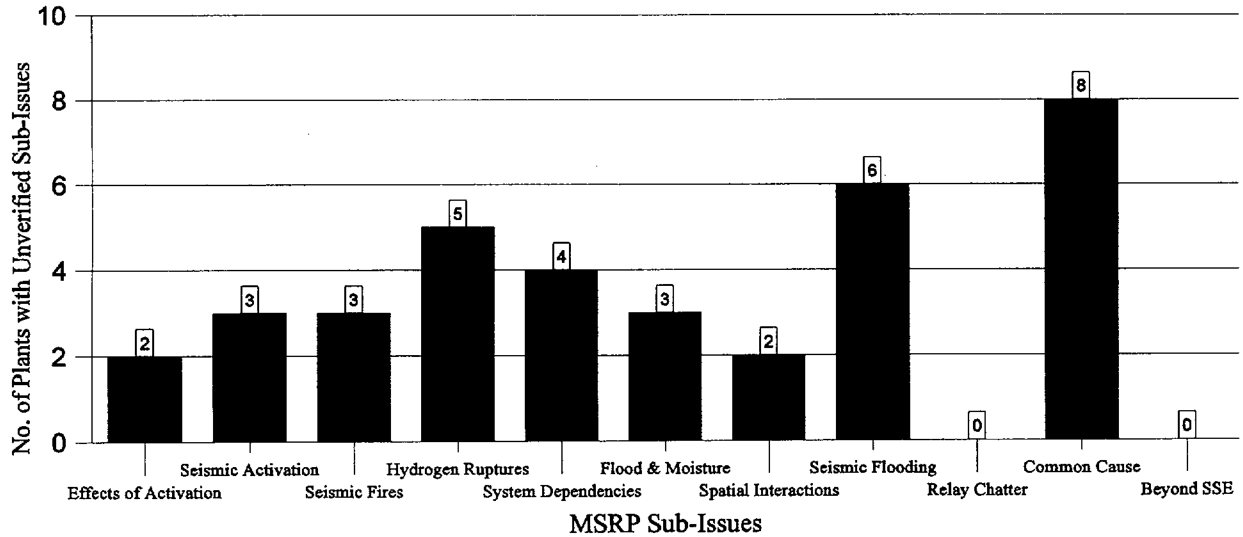

Figure 5.2 Number of unverified GSI-172 issues by issue

5.4.8.2.1 Effects of Fire Suppression System Actuation on Non-Safety-Related and Safety-Related Equipment

All of the IPEEE submittals reported that the licensee had qualitatively examined issues related to inadvertent fire suppression system actuation. To varying degrees, such examinations included the potential for, and effects of, inadvertent fire suppression systems actuation.

In most of the submittals, licensees included considerations related to inadvertent fire suppression system actuation within the scope of their overall seismic walkdown. The most consistent strong points of these evaluations appear to be the treatment of inadvertent fire suppression systems actuation and the identification of concerns regarding potential interaction with safety equipment. However, the level of effort, scope, and detail varied significantly among the IPEEE submittals. Two submittals (LaSalle and St. Lucie) did not include any evaluation. In most other cases, licensees limited their evaluations exclusively to assessing direct impacts on safe shutdown equipment or safety-related equipment.

Many of the submittals did not consider the potential effects of inadvertent fire suppression system actuation on non-safety-related equipment. Most considered non-safety-related equipment to be unnecessary for safe shutdown, or stated that the equipment and floor drains would be adequate to prevent unacceptable internal flooding. See Section 5.4.2 on GSI-57, "Effects of Fire Protection System Actuation on Safety-Related Equipment," for additional discussion related to this issue.

5.4.8.2.2 Seismically Induced Fire Suppression System Actuation

All of the IPEEE submittals reported that the licensees qualitatively examined issues related to seismically induced fire suppression system actuation. To varying degrees, such examinations included the potential and effects of seismically initiated actuation and degradation of fire suppression systems.

In most of the submittals, licensees included considerations related to seismically induced fire suppression system actuation within the scope of their overall seismic walkdown. The most consistent strong point of these evaluations appears to be the treatment of inadvertent actuation of the fire suppression system. However, the level of effort, scope, and detail directed toward addressing issues related to seismically induced fire suppression system actuation varied significantly among the IPEEE submittals. Three submittals (North Anna, St. Lucie, and Turkey Point) did not include any evaluation. In most other cases, licensees limited their evaluations exclusively to assessing direct impacts on safe shutdown equipment.

Many of the submittals did not include a consideration of the potential for seismically induced loss of fire suppression systems. In the remaining cases, some licensees sought to include all relevant plant areas and equipment in their evaluations. Such relevant items include, for instance, fire suppression system components and non-safety-related piping and tanks, which may not be part of the seismic plant model or safe-shutdown equipment list, but may nonetheless be important or may have indirect effects on safety-related equipment.

In a number of the IPEEE submittals, the evaluation of seismically induced fire suppression system actuation resulted in plant improvements. Some of the relevant improvements included strengthening component anchorages, replacing vulnerable (e.g., mercury) relays and switches, and implementing procedures to properly secure transient fire-protection equipment.

For additional information, refer to the discussion on GSI-57, "Effects of Fire Protection System Actuation on Safety-Related Equipment," in Section 5.4.2.

5.4.8.2.3 Seismically Induced Fires

All of the IPEEE submittals reported that the licensees qualitatively examined seismically induced fire interaction issues as part of the treatment of Sandia fire risk scoping study issues. A few licensees performed a PRA study for seismically induced fire-initiating events; albeit the level of detail varied from a simplistic probabilistic analysis to inclusion in their plant's seismic or fire PRA.

In most of the submittals, licensees included seismically induced fire considerations within the scope of their overall seismic walkdown. The level of effort, scope, and detail directed toward addressing seismically induced fire issues varied significantly among the IPEEE submittals. One licensee (LaSalle) did not discuss seismically induced fire evaluations in their IPEEE submittal. In most other cases, licensees limited their seismically induced fire evaluations exclusively to assessing direct impacts on safe shutdown equipment.

Some licensees sought to include all relevant plant areas and equipment in their evaluations of the potential and effects of seismically induced fire events. Such relevant items include, for example, non-safety-related piping and tanks containing flammable materials, which may not be part of the seismic plant model or safe shutdown equipment list, but may have indirect effects on safety-related equipment.

In some of the IPEEE submittals, the evaluations of the seismically induced fire interaction resulted in plant improvements. An example of the relevant improvements is the installation of restraints for gas cylinders.

5.4.8.2.4 Effects of Hydrogen Line Ruptures

All but 5 of the 69 submittals provided sufficient information to verify this MSRP issue. Of these five submittals, two (Hatch and Seabrook) addressed the potential effects of hydrogen tank ruptures, but did not discuss the potential for hydrogen line ruptures. The other three submittals did not specifically discuss the potential failure of hydrogen lines or tanks. The other licensees considered the potential effects of ruptures of hydrogen lines and tanks. These licensees found that the potential rupture of either hydrogen lines or tanks did not significantly contribute to the core damage frequency and, thus, this aspect was considered verified. Licensees typically addressed this issue by performing plant walkdowns following EPRI's FIVE methodology. FIVE calls for licensees to "identify any flammable liquid or gas storage vessel or piping (e.g., hydrogen) and whether these vessels are subject to leakage under seismic conditions."

5.4.8.2.5 Non-Safety-Related Control System/Safety-Related Protection System Dependencies

The dependencies between non-safety-related control systems and safety-related protection systems resulting from external events are related to GSI-147, "Fire-Induced Alternate Shutdown/Control Room Panel Interactions," and the MSRP issue on seismically induced spatial and functional interactions. Generally, licensees took the position that since safe shutdown could be achieved either from the main control room or the alternate shutdown panel(s) using only safety-related equipment, any failure or failures of non-safety-related equipment would not inhibit achieving safe shutdown conditions. All but four submittals provided sufficient information to verify this issue. Licensees provided different levels of detail. Of the four submittals that did not provide adequate information to verify this issue, three did not provide any discussion related to this issue, and one did not address the hot short aspect of this issue. See Sections 5.4.5 and 5.4.8.2.7 for additional discussion related to this issue.

5.4.8.2.6 Effects of Flooding and/or Moisture Intrusion on Non-Safety-Related and Safety-Related Equipment

Frequently, the discussion of this issue in the IPEEE submittals related to the ability to adequately protect safety-related equipment from external flooding. External flooding is covered by the licensees' HFO analyses (see Section 4.3). A satisfactory HFO evaluation verifies the flooding aspect of this issue.

The other aspect of this issue relates to moisture intrusion into equipment. All but three submittals provided adequate information for the staff to conclude that this aspect of this issue was verified. Generally, this information related to the licensees having adequately addressed the potential effects of seismically induced failure or actuation of the fire protection system and the potential effects of misdirected spray from manual fire-fighting activities, since these are the two main sources of water for potential moisture intrusion into equipment. See Section 5.4.2 for additional discussion.

5.4.8.2.7 Seismically Induced Spatial-Functional Interactions

All but two of the IPEEE submittals provided sufficient information on the licensees' examinations related to seismic spatial-functional interaction issues. In most of the submittals, licensees considered seismic spatial-functional interaction within the scope of their overall seismic walkdown (see Chapter 2). However, the level of effort, scope, and detail directed toward addressing seismic spatial-functional interaction issues varied significantly among the IPEEE submittals. In most cases, licensees limited their evaluations of seismic spatial-functional interactions exclusively to assessing the direct impacts on safe shutdown equipment.

In some of the IPEEE submittals, the evaluations of seismic spatial-functional evaluations resulted in plant improvements. Some of the relevant improvements included strengthening component anchorages, anchoring cabinets together, and implementing procedures to properly secure transient fire-protection equipment. In one instance, the licensee evaluated the potential for seismically induced toxic chemical release as part of its seismic interactions walkdown. As a result, the licensee identified a plant-specific improvement related to strengthening the anchorage of an ammonia storage tank.

5.4.8.2.8 Seismically Induced Flooding

Some licensees undertook quantitative assessments of components' seismic capacities related to seismically induced flooding interactions. A few licensees performed a PRA study for seismically induced flooding events, albeit the level of detail varied from simplistic probabilistic analysis to inclusion in their plant's seismic PRA.

In most of the submittals, licensees included seismically induced flooding considerations within the scope of their overall seismic walkdown. However, the level of effort, scope, and detail directed toward addressing seismically induced flooding issues varied significantly among the IPEEE submittals. All but six of the licensees provided adequate information to verify this issue. Of the remaining six submittals, five did not provide any discussion of evaluations related to seismically induced flooding in their IPEEE submittal, and one licensee did not provide adequate information to completely verify this issue. In most other cases, licensees limited their seismically induced flooding evaluations exclusively to assessing direct impacts on safe shutdown equipment.

Some licensees sought to include all relevant plant areas and equipment in their evaluations of the potential for and effects of seismically induced flooding events. Such relevant items include, for example, non-safety-related piping and tanks that may not be part of the seismic plant model or safe-shutdown equipment list, but may nonetheless be important or may have indirect effects on safety equipment.

In some of the IPEEE submittals, the evaluations of seismically induced flood interaction resulted in plant improvements. Some of the relevant improvements include adding seals to waterproof electrical cabinets and implementing enhanced drain inspection procedures. Evaluations of external flooding (see Chapter 4) also addressed this sub-issue.

5.4.8.2.9 Seismically Induced Relay Chatter

All of the submittals provided adequate information to verify this issue. In a few plants, low-ruggedness relays have been encountered in the circuits involving only IPEEE success paths (i.e., IPEEE equipment that was not redundant to USI A-46). Of the 27 licensees that performed a seismic PRA (SPRA) as part of their IPEEE, 14 included relays in the PRA models. Others performed separate evaluations to determine the ruggedness of relays. When relays are explicitly modeled in the PRA, the effect of low-ruggedness relay chatter on accident sequences is clearly identified and quantified. Most of SPRAs did not credit recovery actions in their logic model.

When licensees encountered low-ruggedness relays, they often existed only in alarm circuitry, were assessed as having negligible consequences, or the licensees assumed that operator actions would provide for effective reset. In only limited instances, licensees actually proposed replacing relays specifically on the basis of the analysis for the IPEEE. For additional information, see Section 2.3.1.4.

5.4.8.2.10 IPEEE-Related Aspects of Common Cause Failures Related to Human Errors

All of the 69 IPEEE submittals (which excludes Haddam Neck) provided some treatment or discussion of non-seismic failures and human actions. Of the 69 submittals, 61 provided adequate information to verify this issue, 2 provided adequate information to partially verify this issue, and 6 did not provide adequate information to verify this issue.

For seismic PRAs, operator actions were introduced in seismic event-tree and fault-tree models, which generally reflect the logic used in the plant's internal events PRA. However, the seismic impacts on operator error rates were modeled in a highly variable fashion. In some instances, licensees developed simplified operator error fragilities. In other instances, licensees applied judgemental scaling factors (in relation to the importance of the human action) on internal event error rates, or other means to account for seismically related performance shaping factors.

With regard to the treatment of human actions in IPEEEs that used a seismic margin assessment (SMA), the staff's reviews found that the submittals typically provided only limited discussion of the impact of seismic events on operator error rates. Generally, the SMA IPEEE submittals took the approach of relying on those success paths that are most familiar to plant operators and that use the most reliable equipment. In one SMA, the licensee applied quantitative screening criteria with respect to random failure rates and human error rates. Licensees have generally reported the timing and locations of required human actions, and have commented qualitatively on their reliability.

The approaches varied for quantification of the post-accident human actions retained from the IPEs. A few licensees used the existing IPE HEPs without making any adjustments to reflect the potential impact of fire conditions. These submittals did not address the potential that at least one operator may not be available as the result of fire brigade responsibilities, the fire may result in spurious signals and alarms that would provide confusing information to the operator, or the fire and the presence of even small amounts of smoke might have negative psychological effects on some operators and other plant staff who are needed to respond to the event. Regardless of their approach, few submittals considered these factors in determining HEPs.

Some licensees simply applied a performance shaping factor (PSF) of, for example 5 or 10, as a multiplier on all the existing IPE HEPs to reflect potential influences (e.g., increased stress) that a fire might create for the operators. Some licensees examined each human action and used expert judgement to decide whether a multiplier (or a simple increase in the value) should be applied to reflect fire conditions. Others assigned "conservative" screening values (generally around 0.1, but ranging to 1.0 for events that might be directly influenced by the fire) with the idea of doing a more detailed evaluation, if needed. Finally, some licensees re-evaluated all of the existing HEPs and re-quantified them to more precisely model the potential effects of the fire on human performance.

The licensees' submittals considerated human action failure events. In many cases, licensees identified the human actions that were most important to CDF (or CDF reduction), and considered the potential impact of fire effects on those reliability estimates. For more discussion, see Section 3.4.8.

5.4.8.2.11 Evaluation of Earthquake Magnitudes Greater than Safe Shutdown Earthquake

This issue is verified by licensees providing an acceptable seismic IPEEE. The specific seismic review-level earthquake varies, depending on the plants' location and the IPEEE review level identified in NUREG-1407 (see Chapter 2 for details of the seismic submittals). All submittals provided adequate information to verify this issue.

5.4.8.3 Observations

Even though these MSRP issues were not explicitly identified in either Generic Letter 88-20 or NUREG-1407, a large majority of the licensees (approximately 80%) provided sufficient information in their IPEEE submittals to verify all 11 MSRP sub-issues. Only one plant (LaSalle) had seven unverified MSRP issues. Table 5.7 of Volume 2 of this report identifies the verification of each FRSS issue by plant.

5.4.9 Sandia Fire Risk Scoping Study Issues

5.4.9.1 Issue Description

Section 4.2 of NUREG-1407 includes the following statement:

> The use of an existing fire PRA for the internal fires IPEEE is acceptable, provided the PRA reflects the current as-built and as-operated status of the plant and the licensee addresses the deficiencies of past PRAs that are identified in the Fire Risk Scoping Study (NUREG/CR-5088).

EPRI's FIVE methodology, which the NRC staff concluded was acceptable for use in the fire IPEEE, provides guidance for licensees to use in addressing the Sandia FRSS issues. The following sections discuss each of the five FRSS issues that were to be addressed as part of the IPEEE. As noted below, several of these FRSS issues are closely related, or identical, to other generic issues discussed in this chapter.

5.4.9.1.1 Seismic-Fire Interactions

The issue of seismic-fire interactions primarily involves three concerns. First is the potential that seismic events might result in fires internal to the plant. Such threats might be realized as a result of inadequately secured liquid fuel or oil tanks, breakage of fuel lines, or rocking of unanchored electrical panels (either safety- or non-safety-grade). The second concern is the potential that seismic events might render fixed fire suppression systems inoperable. This could include detection systems, fixed suppression systems, and fixed manual fire-fighting support elements, such as the plant's fire protection system's water distribution system. The third concern is that a seismic event might spuriously activate fixed fire detection and suppression systems. The spurious operation of detectors might both complicate operator response to the seismic event or cause the actuation of automatic fire suppression systems. Actuation of a suppression system may lead to flooding problems, habitability concerns (in the case of CO_2 systems), diversion of suppressants to non-fire areas (rendering them unavailable in the event of a fire elsewhere in the plant), the potential for over-dumping of gaseous suppressants (resulting in over pressurization of a compartment), and spraying of important plant components.

5.4.9.1.2 Adequacy of Fire Barriers

The common reliance on fire barriers to separate redundant components needed to achieve safe shutdown has elevated the risk sensitivity of fire barrier performance. Degraded fire barrier penetration seals and unsealed penetrations in some barriers can contribute to this source of fire risk. Barrier reliability and inter-compartment fire effects relate to the potential that fires in one area might impact other adjacent or connected areas through the spread of heat and smoke. In general, a licensee's fire IPEEE analysis should address this concern by considering the following factors:

- manual fire-fighting activities might allow the spread of smoke and heat through the opening of access doors, and
- failure of active fire barrier elements, such as normally open doors, water curtains, and ventilation dampers, would compromise barrier integrity.

5.4.9.1.3 Smoke Control and Manual Fire-Fighting Effectiveness

Sensitivity studies have shown that prolonged fire-fighting times can lead to a noticeable increase in fire risk. Smoke, identified as one of the major contributors to prolonged response times, can also cause misdirected suppression efforts and hamper the operator's ability to safely shut down the plant. This issue evolved as GSI-148, which is discussed in Section 5.4.6 of this report.

5.4.9.1.4 Equipment Survival in a Fire-Induced Environment

The FRSS investigated the potential susceptibility of equipment damage to indirect or secondary fire involvement through the environment created by fires, fire suppression, and the spurious operation of fire suppression systems. The FRSS found that past spurious actuation of suppression systems had a range of effects, including induced plant scrams. Several events were identified in which significant degradation of plant operability resulted. This issue is assessed as part of GSI-57, "Effects of Fire Protection System Actuation on Safety Related Equipment," which is discussed in Section 5.4.2 of this report.

5.4.9.1.5 Fire-Induced Alternate Shutdown/Control Room Panel Interactions

Control system interactions involving a combination of fire-induced failures and spurious actuation, and high-probability random equipment failures, were identified as potential contributions to fire risk. Sensitivity studies were performed which indicated that these interactions could have a significant impact on the fire core damage frequency. This issue was later classified as GSI-147, which is discussed in Section 5.4.5 of this report.

5.4.9.2 Findings and Related Plant Modifications

Of the 69 submittals, 16 did not provide adequate information to verify one or more of the sub-issues in the FRSS. Twenty-seven licensees used the FIVE methodology in addressing the FRSS issues. Figure 5.3 shows the distribution of unverified or partially unverified FRSS issues by issue, while Figure 5.4 shows the distribution of unverified or partially unverified issues by plant. Figure 5.3 shows that the most common unverified FRSS issue (14 plants) is related to smoke control and manual fire-fighting effectiveness. This is not surprising, for as with GSI-148, if a licensee did not take credit for manual fire-fighting actions in their

IPEEE fire analysis, there might not be sufficient information to verify this FRSS issue. For additional discussion directly related to this issue, see Section 5.4.6.

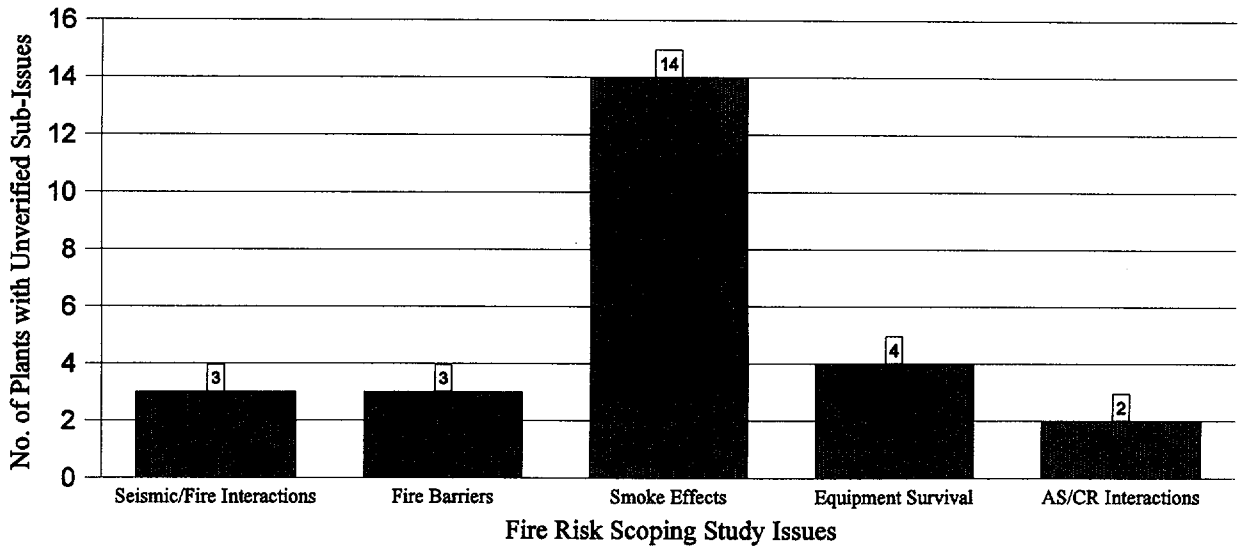

Figure 5.3 Number of unverified FRSS issues by issue

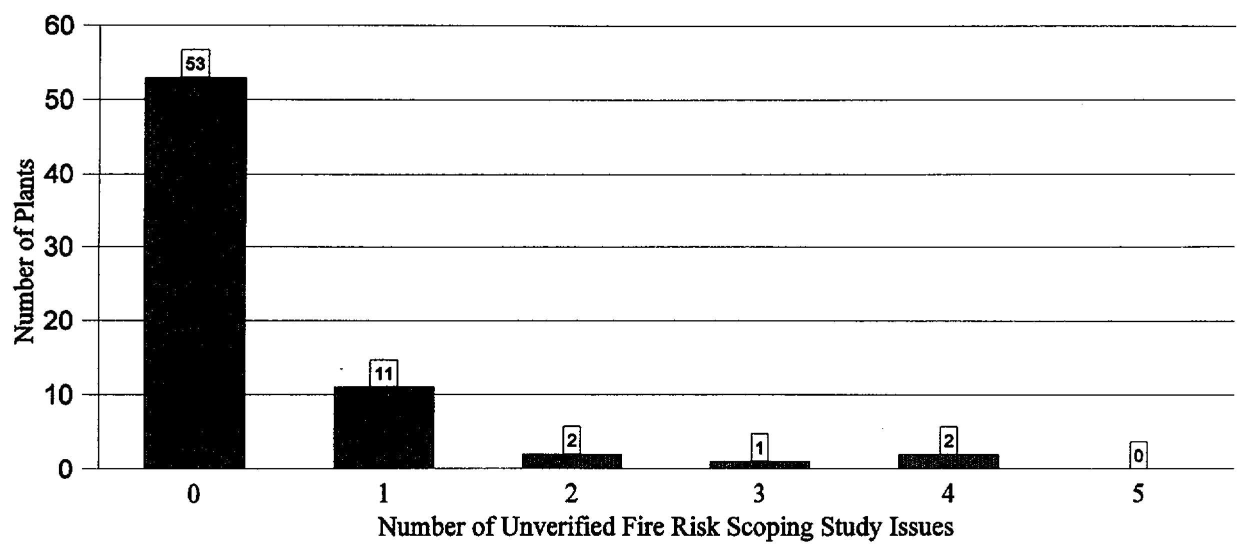

Figure 5.4 Number of unverified FRSS issues by plant

Figure 5.4 shows that two licensees each had four unverified FRSS issues. Table 5.8 of Volume 2 of this report shows that one of these two plants (LaSalle) did not provide information to explicitly address these four issues, and the other plant (Hatch) provided information to partially verify each of the four issues. Except for these two licensees, almost all of the FRSS issues (excluding smoke effects) were verified for most of the plants.

Table 5.8 of Volume 2 of this report identifies the verification of each FRSS issue by plant. This table also provides comments on plant-unique or interesting characteristics related to these issues and why these issues were partially or not fully verified.

Only one plant (Surry) explicitly identified any plant modifications that directly related to the FRSS issues. In this case, the licensee modified some electric circuits to ensure that the diesel generators and the alternate shutdown panel could be isolated from the control room and to reduce the likelihood of spurious power operated relief valve actuations. Although other plants did not explicitly identify plant enhancements related to the FRSS issues, plant modifications identified for other issues could also be an improvement for one or more of the FRSS issues (e.g., securing bottle gas tanks related to seismic-fire interactions).

5.4.9.2.1 Seismic-Fire Interactions

All but 3 of the 69 submittals provided adequate information to verify this FRSS issue. Licensees frequently assessed the potential seismic-fire interactions as part of their seismic and fire walkdowns. The potential for seismic events to initiate a fire related to the potential for an earthquake to result in a rupture of combustible gas lines, cylinders, or tanks. The most frequent plant enhancement related to this issue was to ensure that the existing procedures for securing the cylinders were followed. Combustible fluids are generally not stored or used near safety-related equipment. Generally, the tanks are outside, and the primary use of hydrogen is in the turbine building for generator cooling. Acetylene is stored in areas with no safety-related equipment.

The licensees also considered the potential for seismically induced failure of the fire protection system. This included evaluating potential failures that could adversely affect safety-related structures, systems, or components. Generally, the licensees identified the fire protection system piping to be designed to the seismic Category II/I criteria, or identified similar standards if they did not explicitly refer to the II/I criteria. The II/I criteria states that any seismic Category II (i.e., non-seismic Category I) structure, system, or component that is installed over a seismic Category I structure, system, or component will not fail in such a manner as to adversely affect the seismic Category I structure, system, or component; however, the seismic Category II structure, system, or component may no longer be functional. Some licensees identified that although the fire protection system was not designed as seismic Category I, a review of the system indicated that it would likely remain functional after an earthquake (e.g., some hangers might fail, but the piping would remain essentially intact).

Licensees generally used one of three methods to address the potential for seismic activity to actuate the fire protection system. First, most water systems are of the dry pipe design (i.e., a valve needs to open to flood the spray lines, and the fusible link in the sprinkler heat needs to melt before water is discharged from the system). Having both of these events occur solely as a result of a seismic event was deemed to be unlikely. A second type is the wet pipe fire protection system design. This design is similar to the dry pipe design except that water is maintained at the sprinkler head. In this case, the fusible link prevents discharge. This fusible link is not susceptible to failure from dust that might be stirred up as a result of a seismic event. Finally, there are gas suppression systems that use Halon or CO_2 as the fire suppressant. Inadvertent activation of these systems would not aversely affect the equipment in an area that was not already damaged by a fire (e.g., in the cable spreading or switchgear rooms). These gas suppressant systems are for limited areas and are independent of the water suppressant systems used elsewhere in the plant.

5.4.9.2.2 Adequacy of Fire Barriers

All but 3 of the 69 submittals provided adequate information to verify this FRSS issue. Licensees typically addressed barrier integrity in their submittals by discussing the plant's inspection, surveillance, and maintenance program that was used to verify the integrity of penetration seals (including door and hatch seals) and doors. The percentage of the seals that were inspected, as well as the interval of inspection, varied considerably from plant to plant. The inspections ranged from a small percentage of the accessible seals per calendar quarter to a larger percentage every 18 months (refueling outage). Licensees also cited inspection procedures ensure that fire doors remain closed. Welding activities could necessitate having doors open or partially open for hoses or cables to pass through, thereby breaching a fire barrier. Therefore, fire watches were commonly identified as the means to prevent welding activities from starting fires and to quickly suppress fires that might occur.

Given the licensees' programs for barrier integrity, the submittals typically assumed that the fire barriers would perform their intended function, as designed. A few licensees considered the potential consequences if a fire were to breach a fire barrier and adversely affect equipment in the adjacent fire area. Licensees usually addressed these consequences by considering the fire barrier to be ineffective with some small probability. Generally, the licensees found that, in these cases, the multi-zone fire scenarios were not a significant contributor to the plant's fire CDF.

Those licensees that took credit for or provided information related to manual fire-fighting activities usually included some discussion of the effects of smoke. Generally, the submittals indicated that the large volume of the adjacent fire area would dilute any smoke and heat that entered through a door opened for manual fire-fighting purposes. The licensees concluded that the results of such a fire barrier breach would not inhibit fire-fighting activities.

5.4.9.2.3 Smoke Control and Manual Fire-Fighting Effectiveness

Of the 69 submittals, 14 did not provide sufficient information to verify this FRSS issue. Most submittals included some discussion of the fire brigade training. Some train under live smoke conditions, while one licensee (Grand Gulf) also simulates the actual plant configuration and changes the configuration for each fire drill. Since this FRSS issue is the same as GSI-148, "Smoke Control and Manual Fire-Fighting Effectiveness," see Section 5.4.6 of this report for more discussion concerning this issue.

5.4.9.2.4 Equipment Survival in a Fire-Induced Environment

All but 4 of the 69 submittals provided adequate information to verify this FRSS issue. Many licensees identified that some, or all, of their water-based fire protection systems to require two diverse actions for initiation (pre-action type). One action would be for a smoke detector to open a supply valve in the fire protection system, while the second action is the fire's heat to melt the fusible link in the sprinkler head. For this type of system, the licensees concluded that inadvertent activation of the fire protection system by a seismic event or dust was not a problem.

Licensees also reviewed the impact of CO_2 or Halon protective system actuation as it relates to the potential effects on personnel (e.g., control room operators) and equipment (e.g., operation of the diesel generators) in the area. Licensees usually dismissed potential problems from these systems as insignificant to safety or beyond the scope of this generic issue. Data on the effects of smoke and fire suppressants on equipment is limited and beyond the scope of the IPEEE program.

Some licensees discussed the potential for the effects of fire to adversely affect equipment that is not directly involved with the fire. This includes potential effects of corrosion, buildup of soot, or other combustion products. Those that did discuss this aspect stated that potential damage would occur over a much longer period than required to establish cold shutdown. Corrective maintenance would resolve any long-term problem that might be caused by these mechanisms. The remaining submittals did not discuss the impact of combustion products on equipment operability.

5.4.9.2.5 Fire-Induced Alternate Shutdown/Control Room Panel Interactions

All but 2 of the 69 submittals provided adequate information to verify this FRSS issue. Generally, the submittals identified that the plants have the ability to transfer adequate control from the control room to alternate locations to achieve plant safe shutdown conditions (i.e., the alternate location is electrically independent of the control room); control would be regained after being transferred from the control room to the alternate shutdown locations; the review considered spurious actuation of components; and the potential loss of power to equipment was addressed by feeding the alternate shutdown equipment through a separate, independent breaker or fuse. Since this FRSS issue is the same as GSI-147, "Fire-Induced Alternate Shutdown/Control Room Panel Interactions," see Section 5.4.5 of this report for more discussion concerning this issue.

5.5 Summary and Conclusions

This chapter discusses a total of 31 IPEEE-related unresolved safety issues and generic safety issues, including USI A-45, GSI-57, GSI-103, GSI-131, GSI-147, GSI-148, GSI-156 (9 SEP issues), GSI-172 (11 MSRP issues), and five FRSS issues. Nine of these issues were explicitly discussed in Supplement 4 to Generic Letter 88-20 and NUREG-1407 (USI A-45, GSI-57, GSI-103, GSI-131, and the five FRSS issues). The other 22 issues were not explicitly discussed in the Generic Letter 88-20 or NUREG-1407. However, the NRC believes that the plant-specific analyses that were requested in the scope of the IPEEE program could also be used, through a satisfactory IPEEE submittal review, to evaluate and verify the external event aspects of these generic issues. Section 5.4 of this report discusses each of these issues, the related findings, and plant modifications. Detailed plant-specific tables concerning these USIs and GSIs are provided in Section 5 of Volume 2 of this report.

One of the major achievements of the IPEEE program was the verification of a large majority of these generic issues. As shown in Table 5.2, most of the plants verified a large majority of these issues. Figure 5.5 graphically illustrates these results. Of the 69 submittals, 44 provided sufficient information to verify all 31 USIs and GSIs. The remaining 25 submittals had one or more generic issue(s) unverified or only partially verified[6]. USI A-45, GSI-131, and GSI-156 (9 SEP issues) were fully verified for all plants. Of the other

[6] If a licensee's submittal did not address a generic issue, but did not overlook a potential vulnerability, the NRC's Staff Evaluation Report for that plant identified te omission as a weakness in the submittal. In such cases, the submittal still meets the intent of the IPEEE program, but the GSI may not be "verified" for that plant. For those issues that have not been completely verified, the NRC staff will determine if any additional actions or assessments are needed to verify these GSIs. This follow-up will

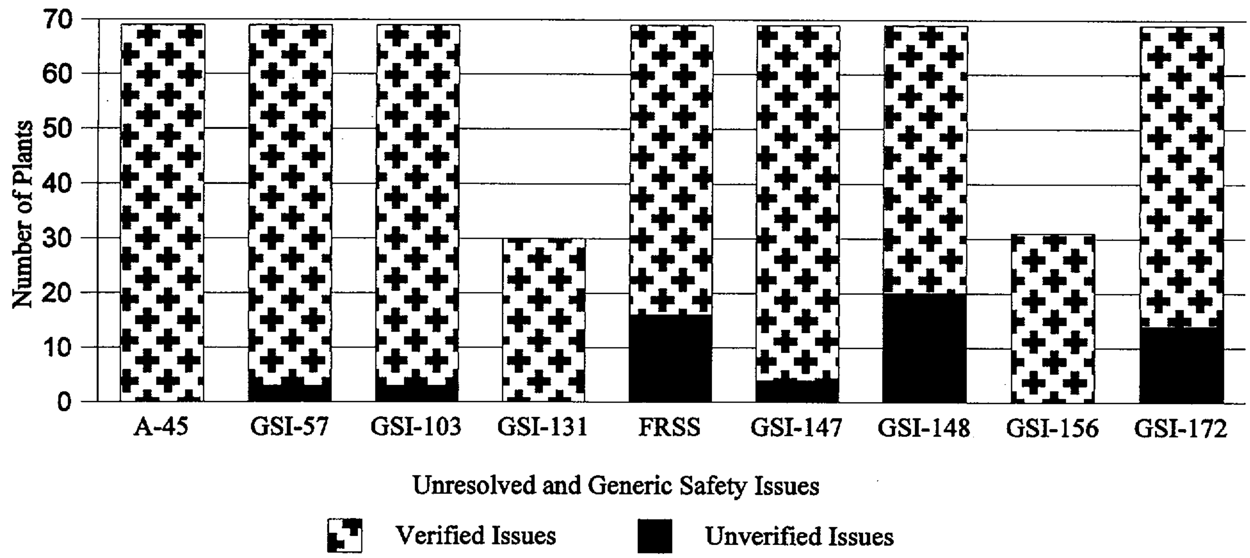

Figure 5.5 Number of unverified or partially verified generic issues by plant

generic issues, GSI-57, GSI-103, and GSI-147 were verified for approximately 95% of the plants. GSI-172 and the FRSS issues were verified for almost 80% of the plants.[7] Even the issue that was most commonly unverified, GSI-148, was still verified for 70% of the plants. Not surprisingly, those issues that were explicitly identified in Supplement 4 to Generic Letter 88-20 or NUREG-1407 had a higher percentage of verification than those that were not explicitly identified. Nevertheless, even those issues that were not identified were verified for most of the plants. One submittal (LaSalle) did not provide any information to verify generic issues. Those sub-issues that could be verified relied on information that could be deduced from an old PRA.

With regard to GSI-148, a number of licensees did not take credit for manual fire-fighting actions in their IPEEE fire analyses. Although this assumption is conservative from a PRA standpoint (i.e., could lead to a higher estimated fire CDF), the submittals for these cases did not consider the potential damaging effects of misdirected suppression on adjacent safety-related equipment. Therefore, this generic issue was not considered verified for those plants. One of the FRSS issues, "Smoke Control and Manual Fire-Fighting Effectiveness," is essentially the same as GSI-148. As shown in Figure 5.3, the most commonly unverified FRSS issue by far was the issue of smoke effects. Therefore, if a submittal did not provide adequate information to verify GSI-148, that submittal also lacked adequate information to verify one of the FRSS issues. This contributed to the FRSS issues being only partially verified for a number of plants.

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be done separately from the IPEEE program.

[7] GSI-172 (MSRP) and the FRSS issues actually comprised 11 and 5 separate issues, respectively. All plants verified at least some of these MSRP and FRSS issues. If one or more individual MSRP or FRSS issue(s) were not verified for a plant, Table 5.2 identifies the issue as "partially verified" for that plant. Figure 5.5 graphically reflects the same information as Table 5.2.

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GLOSSARY

Active fire barrier — a fire barrier element that must be physically repositioned from its normal configuration to an alternative configuration in order to provide its protective function. Examples include ventilation system fire dampers and normally open fire doors.

Anomaly — an observed plant condition that deviates from a normal configuration or otherwise apparently fails to satisfy expected criteria.

Anticipated transient without scram (ATWS) — a perturbation in the state of some system or component at full reactor power that initiates a deviation from the full-power, steady-state operating conditions that has been previously considered and analyzed which would normally result in a reactor scram. However, in this case, the reactor does not scram, either automatically or manually.

Appendix R fire area — an area, as defined in the analysis pursuant to Appendix R to Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50), "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," that is sufficiently bounded by fire barriers such that it will withstand the fire hazards within the fire area and, as necessary, will protect important equipment within a fire area from a fire outside the area. A fire area must be made up of rated fire barriers with openings in the barriers provided with fire doors, fire dampers, and fire penetration seal assemblies having a fire resistance rating at least equivalent to the barrier in which it is installed.

Appendix R fire zones — subdivisions of a fire area, as specified in Appendix R to 10 CFR Part 50.

Appendix R requirements — fire protection requirements specified in Appendix R to 10 CFR Part 50. (It should be noted that while some Appendix R requirements apply to all plants operating before January 1, 1979, plants licensed after January 1, 1979, are not subject to Appendix R requirements. Instead, these plants must meet the fire protection condition(s) of their licenses, which are based upon the guidelines of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports of Nuclear Power Reactors — LWR Edition," June 1987, specifically Branch Technical Position CMEB 9.5-1, which mirrors Appendix R with additional information.)

"Bad actor" relay — a low-ruggedness relay, as defined in guidance and procedures pertaining to USI A-46 and the Seismic Quantification Utilities Group (SQUG).

Barrier failure — the breach of a fire barrier, by a fire or other cause, which could permit propagation of a fire or its combustion products across the barrier.

Bounding analysis — an analysis that intentionally makes use of methods and assumptions (e.g., those pertaining to parameters describing a hazard, a resulting initiating event, and a plant's resistance to the initiator) designed to result in an upper-bound or demonstrably conservative estimate of risk.

Charleston Earthquake Issue — an issue initiated by a 1982 U.S. Geological Survey letter that pointed out the possibility that large, damaging earthquakes have some likelihood of occurring at locations where such events may not previously have been considered in developing past licensing decisions. (As a result of work carried out by the NRC and EPRI to resolve this issue, eight plants at five Eastern U.S. sites were identified as having a sufficient likelihood of being affected by large, damaging earthquakes beyond the licensing bases, such that further assessment was deemed to be warranted.)

Common cause failure (also referred to as "common mode failure") — a single event, action (e.g., improper maintenance activity), or condition (e.g., stress corrosion cracking) that adversely affects two or more similar or identical components at the same time. (Since this report deals with external events, the common cause failure can also be an external event that affects multiple (similar or dissimilar) components in the same area.)

COMPBRN — a computer code described in EPRI NP-7282, "COMPBRN IIIE: An Interactive Computer Code for Fire Risk Analyses," May 1991.

Component — an item of plant equipment (e.g., a pump, valve, pipe, etc.) or a structural feature (e.g., a building, masonry wall, stack, etc.) that is designed to perform a particular function. (For purposes of system modeling, a component is the lowest level of detail used in representing a piece of plant hardware and defining its associated failure as a basic event.)

Conditional core damage probability (CCDP) — a probability of reaching core damage given an event (initiator), in combination with a specific (degraded or normal) plant condition. (For example, the initiator might be a wind-induced loss of offsite power, and an associated degraded plant condition might be crimping of an exposed diesel generator exhaust stack resulting from a wind-induced missile. In this case, the CCDP would be determined by evaluating the plant model for a loss of offsite power initiator where either an increased failure probability or guaranteed failure of at least one diesel generator is assumed.)

Conservative deterministic failure margin (CDFM) — an estimate of the high-confidence of low-probability of failure (HCLPF) capacity of a component, determined in accordance with the procedure recommended in EPRI NP-6041.

Containment failure modes — a mutually exclusive set of descriptive states used to categorize the characteristics of containment failure. (For example, such descriptive states might consist of "early isolation failure," "late isolation failure," "early containment bypass failure," "early over-pressure failure," etc.)

Containment performance — the ability of a nuclear plant containment to fulfill its intended function in the event of challenges presented by a severe accident. (Such ability can be assessed through qualitative and/or quantitative evaluation. A quantitative measure of containment performance would be the conditional probability of containment failure given core damage.)

Control systems interaction — the potential of fire to adversely affect the ability of plant operators to achieve safe shutdown from either the control room or the remote shutdown panel as a result of fire-induced circuit failures. (For example, a fire may damage common circuits or cables in a way interferes with the ability to achieve safe shutdown conditions. Control systems interaction is identified as Generic Safety Issue (GSI) 147.)

Core damage — a state of clad oxidation and fuel damage caused by a prolonged uncovering and heating of the reactor core, as a result of an imbalance in heat generation and heat removal.

Core damage frequency (CDF) — the frequency, per reactor-year, of the occurrence of severe accidents that lead to core damage.

Cross-zone analysis — the analysis of a potential fire scenario involving fire propagation between adjacent fire zones.

Cut set — any combination of a set of events (e.g., occurrence of an initiating event and component failures) that, if they occur, would result in an undesirable condition (e.g., onset of core damage or containment failure).

Dependency — requirement external to a structure, system, or component (SSC), and upon which the SSC's function depends.

Design basis event — any of the events specified in a nuclear power plant's licensing basis that are used to establish acceptable performance for safety-related functions. (Such events include anticipated transients, design basis accidents, external events, and natural phenomena.)

Dominant contributor — an accident class that has a major impact on the total core damage frequency, or a containment failure mechanism that has a major impact on the total radionuclide release frequency.

Eastern U.S. seismicity issue — formerly the Charleston Earthquake Issue. (See "Charleston Earthquake Issue.")

EPRI seismic margin assessment (SMA) methodology — a methodology, described in EPRI NP-6041, for seismic assessment of a plant and determination of component and plant HCLPF capacities, which uses success paths as the approach for systems modeling.

Event tree — a quantifiable logical network that begins with an accident initiator or condition; progresses through a series of branches that represent possible system performances, human actions, or phenomenological behaviors; and ultimately leads to either a safe, stable state or an undesirable one, such as core damage or containment failure.

External event — an accident initiator that originates outside a nuclear power plant's internal systems, and in combination with safety system failures and/or operator errors, may induce core damage accident sequences. (Examples of external events include earthquakes, tornadoes, external floods, and fires.)

External flood — a flood initiated outside the plant that can affect the operability of internal plant systems.

Fault tree — a graphical representation that shows the logical relationships among possible basic failure events, and provides a concise and orderly description of the various combinations of such events that may occur within a system and could result in some predefined, undesirable event for that system.

Feed-and-bleed — a method to provide core cooling in a pressurized water reactor (PWR) (without the use of feedwater or steam generators) by providing (feeding) primary coolant makeup to the core, while removing decay hear by opening the pressurizer power-operated relief valves (PORVs) or safety valves to remove (bleed) primary fluid having elevated temperature.

Fire area — a physical area bounded on all sides by rated fire barriers. (See also "Appendix R fire area.")

Fire barrier — elements of construction (walls, floors, and their supports), which may incorporate beams, joists, columns, penetration seals or closures, fire doors, and fire dampers that are rated by approving laboratories (usually in terms of hours of resistance to fire), and are used to prevent the propagation of fire.

Fire compartment — in fire analysis, an enclosure or space bounded by non-combustible barriers, where heat and products of combustion generated from a fire will be substantially confined within the enclosure.

Fire compartment interaction analysis (FCIA)— a procedural step in the EPRI fire-induced vulnerability evaluation (FIVE) methodology, in which qualitative consideration is given to the potential for interacting fire spread between compartments and the consequences of such fire spread on plant shutdown.

Fire damage modeling — modeling of all pertinent and necessary fire damage sequences (including fire scenarios and fire-induced sequences).

Fire-induced vulnerability evaluation (FIVE) — a quantitative screening technique sponsored by the EPRI under the guidance of the Severe Accident Working Group of the Nuclear Management and Resources Council (NUMARC) and the industry's experts, for the purpose of addressing the fire portion of licensees' IPEEE studies.

Fire PRA methodology — the set of procedures, based on probabilistic risk analysis, for estimating the core damage frequency attributable to fire events.

Fire zones — subdivisions of a fire area. (See also "Appendix R fire zones.")

Focused-scope — a term used in NUREG-1407 to designate a somewhat narrowed set of aspects, relative to the broader full-scope aspects, to be included in the seismic IPEEE assessment for a specified group of nuclear power plants. The plants in this category are to perform a detailed walkdown of the safe shutdown equipment list (SSEL), an evaluation of low-ruggedness relays, a screening assessment of structures and SSEL items for a 0.3g peak ground acceleration (PGA) review-level earthquake (RLE), calculation and reporting of HCLPF capacities for the weaker elements, and determination and reporting of the plant's HCLPF capacity.

Fragility — the conditional probability that a component, system, or plant will fail, given the occurrence of a specified value of a load parameter (e.g., in the case of seismic fragility, the load parameter is typically a measure of ground acceleration). A component fragility curve, which is equivalent to the probability distribution function of the component's capacity, is used in a PRA to determine the component's failure probabilities under various load levels.

Free field — a location at which the ground motion from a seismic event can be recorded without experiencing a measurable influence of ground-motion effects caused by the dynamic response of constructed features.

Free-field peak ground acceleration (PGA) — peak acceleration of the ground motion experienced in a seismic event for free-field conditions.

Full-scope — a term used in NUREG-1407 to designate the broader set of aspects, relative to the focused-scope aspects, to be included in the seismic IPEEE assessment of a specified group of plants. The plants in this category are to perform a seismic IPEEE that goes beyond the focused-scope assessment, particularly in regard to the breadth of relay chatter evaluation, the effort expended in investigating potential soil failures, and the list of components for which HCLPF calculations are performed.

Functional interaction — the potential effects of one component or system upon another as a result of their functional interdependencies.

Generic implementation procedure (GIP) — the screening guidance given in the "Generic Implementation Procedure for Seismic Verification of Nuclear Power Plant Equipment," which was developed under the sponsorship of the Seismic Qualification Utility Group (SQUG).

Generic issue (GI) — A concern that may affect the design, construction, or operation of all, several, or a class of nuclear power plants, which either does not affect safe operation of the plant or the safety significance of the issue has not yet been determined.

Generic Letter 88-20 — a letter issued by the NRC to all licensees on November 23, 1988, which requested that U.S. nuclear power reactor licensees submit an individual plant examination (IPE) for severe accident vulnerabilities for each licensed nuclear power plant.

Generic Letter 88-20, Supplement 4 — a letter issued by the NRC to all licensees on June 28, 1991, which requested that U.S. nuclear power reactor licensees submit an individual plant examination of external events (IPEEE) for severe accident vulnerabilities to external events for each licensed nuclear power plant.

Generic Letter 88-20, Supplement 5 — a letter issued by the NRC to all licensees on September 8, 1995, which notified all U.S. nuclear power reactor licensees about modifications to the seismic reviews that are to be performed as part of the IPEEE program for focused-scope and full-scope plants.

Generic safety issue (GSI) — according to NUREG-0933, "A Prioritization of Generic Safety Issues," a GSI is a safety concern that may affect the design, construction, or operation of all, several, or a class of nuclear power plants, and may have the potential for safety improvements and promulgation of new or revised requirements or guidance.

Ground motion — the strength of shaking experienced at a specified location within the ground or on the ground surface, which is usually described for engineering purposes by either a time history of ground acceleration or a response spectrum that conveys the strength of response accelerations of simple harmonic oscillators versus their vibration periods or frequencies.

Hazard — a potential source of risk (e.g., combustible materials, high-pressure piping, chemical solutions, storms, earthquake sources, landslides, meteors, etc.).

Hazard curve — A curve conveying the annual rate of occurrence of a hazardous event versus the value of a parameter that characterizes the severity of the hazard. (Hazard curves are most often used to quantify the threat of various earthquake ground motions, extreme wind speeds, and extreme flood levels.)

High-confidence of low-probability of failure (HCLPF) capacity — an earthquake acceleration level for which a given component, system, or plant is evaluated as having a 95% confidence that the chance of its failure is 5%.

High wind, flood, and other (HFO) external events — the external events examined in an IPEEE, excluding seismic and fire events. HFO events include high winds and tornadoes, external floods, transportation and near facility accidents, and other unscreened or plant-unique hazards.

Hot short — an electric cable failure mode, resulting from a fire, which involves making an electrical connection between a conductor with power and a conductor that does not currently have power, without a simultaneous short-to-ground or open-circuit condition. Such a fault might, for example, simulate the closing of a control switch, cause errors in an instrument reading, or result in the application of power to an unpowered circuit.

Human error probability (HEP) — (See "Human error rate.")

Human error rate — a measure of the likelihood that an operator will fail to initiate the correct, required, or specified action or response needed to allow the continuous or correct functioning of an item of equipment. (Human error rate and human error probability are used interchangeably.)

In-core flux mapping (ICFM) system — a system used in a PWR to measure the strength and distribution of neutron flux in the reactor core.

Individual plant examination (IPE) — an evaluation to identify any plant-specific vulnerabilities to severe accidents initiated by internal events, including internal flooding, during full-power operation. (Generic Letter 88-20 requested that each licensee of a United States nuclear power plant perform such an evaluation for its plant(s).)

Individual plant examination of external events (IPEEE) — an evaluation to identify any plant-specific vulnerabilities to severe accidents initiated by external events during full-power operation. (Generic Letter 88-20, Supplement 4, requested that each licensee of a United States nuclear power plant perform such an evaluation for its plant(s).)

Interfacing system loss-of-coolant accident (ISLOCA) — an accident in which reactor coolant is released at high pressure into a low-pressure system, resulting in a loss of reactor coolant that cannot be isolated.

Internal events — accident initiators (including internal flooding) that originate within a nuclear power plant and, in combination with safety system failures and/or operator errors, may induce core damage accident sequences.

Internal fire — a fire initiated anywhere within the plant boundaries, including areas within plant structures and buildings, as well as contiguous outdoor areas such as the electrical switchyard and transformer areas.

Internal flood — a flood initiated within the plant that can affect the operability of internal plant systems.

Level 1 analysis — an identification and quantification of the sequences of events leading to the onset of core damage.

Level 2 analysis — an evaluation of containment response to severe accident challenges, including quantification of the mechanisms, quantities, and likelihoods of radioactive material releases from the containment given core damage accident sequences.

Loss-of-coolant accident (LOCA) — an accident caused by a break in the reactor coolant system pressure boundary.

Low-ruggedness relay — a relay or relay-type device (switch/contact) that has the potential to change state, or to oscillate between states (i.e., chatter), under a relatively low-intensity seismic event.

Minimal cut set — a necessary and sufficient combination of events (e.g., occurrence of an initiating event and component failures) that would result in some undesirable condition (e.g., onset of core damage or containment failure). (See also "Cut set.")

Mission time — the time period that a system or component is required to be operable in order to carry out its intended mission. (For example, a containment spray mission time of 24 hours implies that containment sprays are required to be operable for 24 hours following their demand, in order to prevent containment failure from occurring within that time period.)

Modified focused-scope — a focused-scope seismic evaluation that makes use of the relaxations and other provisions described in GL 88-20, Supplement 5.

Modified full-scope — a full-scope seismic evaluation that makes use of the relaxations and other provisions described in GL 88-20, Supplement 5.

Multiple system responses program (MSRP) — the program described in NUREG/CR-5420, "Multiple System Responses Program — Identification of Concerns Related to a Number of Specific Regulatory Issues."

National Fire Protection Association (NFPA) codes and standards — consensus codes and standards intended to minimize the possibility and adverse consequences of fires.

NEI 91-04, "Severe Accident Closure Guidelines" — guidelines proposed by the Nuclear Management and Resources Council (NUMARC) (now, the Nuclear Energy Institute (NEI)) that are intended to identify vulnerabilities that may lead to a severe accident, and that have been proposed as a basis for resolving severe accident issues.

NRC seismic margin assessment (SMA) methodology — a methodology for seismic assessment of a plant and determination of component and plant HCLPF capacities, which uses event tree and fault tree modeling instead of the success path approach that has been adopted in the EPRI SMA methodology.

NUREG-1407 — a report issued by the NRC in June 1991, entitled "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities." This report provides guidance for performing and reporting the results of the IPEEE analyses.

Outlier — a component that cannot be screened out because a condition that violates one or more key criteria of standard screening tables is encountered in a seismic walkdown or documentation review.

Passive component — a component, or part of a component, that performs its intended function without any moving parts or changes in state. (Examples of passive components include tanks, piping runs, valve bodies, and ductwork.)

Passive fire barrier — a fire barrier that provides its protective function while in its normal orientation, without any need to be repositioned. (Examples of passive fire barriers include walls and normally closed fire doors.)

Peak ground acceleration (PGA) — for purposes of IPEEEs, the PGA is the same as the "free-field peak ground acceleration."

Performance shaping factor (PSF) — an influence on the performance of an operator. (PSFs are a key underlying aspect of the concept that human error rates for a set of specified actions can be derived by investigating how a small set of influences affect the likelihood of success or failure of the operator(s). PSFs include such items as training, experience, availability and quality of a procedure, stress, interdependence among operators, environment, and timing.)

Plant — a general term used to refer to a nuclear power facility, including one having a single reactor unit or multiple units.

Plant-level capacity — the quantification of a plant's ability to resist the effects of a given hazard. (Plant-level seismic capacity is typically conveyed by a fragility curve or an HCLPF value. In the EPRI SMA methodology, the plant-level seismic capacity can be conveniently approximated as the lowest HCLPF capacity among those components (including structures) that are relied upon to achieve safe shutdown conditions in the most rugged success path. In the NRC SMA methodology, the plant-level seismic capacity can also be approximated if the Boolean expression for core damage and the HCLPF capacities for components included in this expression are known.)

Plant logic model — a mathematical representation that simulates the behavior of a plant in response to an initiating event. The mathematical representation is used to (a) delineate sequences of events that could result in a state of core damage or a state of safe shutdown, and (b) to quantify the frequencies of such event/accident sequences. A plant logic model typically involves the development of event trees and associated fault trees that describe the combinations of basic events leading to the event-tree top events.

Probabilistic risk assessment (PRA) — an analytical process that quantifies the likelihood of possible adverse consequences. For a nuclear power plant, this process focuses on evaluating the design, operation, and maintenance of a plant in regard to potential severe accidents and adverse effects on the health and safety of the public. The risk evaluation process involves three sequential parts or "levels" (Level-1 addresses potential accident sequences leading to core damage; Level-2 addresses potential releases of radiological materials outside of the containment in the event of core damage; and Level-3 addresses potential adverse health, safety, and environmental consequences resulting from transport of the radiological elements in the event of radiological releases.)

Probable maximum precipitation (PMP) — the probable maximum rainfall, as stated in Generic Letter 89-22. (The PMP pertains to phenomena associated with spatially and temporally localized intense precipitation. Such phenomena are usually distinct from phenomena associated with the probable maximum flood (PMF), which generally results from a longer-term collection of rainfall distributed within a drainage basin and subsequent transport of water (i.e., flood routing) to the site location of interest.)

Qualified cable — a cable that is certified to meet all of the requirements of the IEEE standard No. 383 (including both the flame spread and the LOCA exposure test protocols).

Random failure — an independent, unrelated failure of which an occurrence can be represented by a probability distribution. (In IPEEEs, this term typically refers to failure events that are not caused by, or related to, the external event being analyzed.)

Rated fire barrier — a fire barrier with a fire endurance rating established in accordance with the test procedures of NFPA 251, "Standard Methods of Fire Test of Building Construction and Materials."

Reactor coolant pump (RCP) seal LOCA — a loss-of-coolant accident resulting from a failure of a reactor coolant pump seal.

Reactor-year — 365 full days (8,760 hours) of operation of a single reactor unit at full or partial power. (A reactor-year does not include the shutdown and restart intervals or the downtime of the reactor.)

Recovery action — an operator action intended to restore equipment that has failed or been rendered unavailable (e.g., as a result of testing and maintenance) back to an operable status.

Reduced-scope — a term used in NUREG-1407 to designate a limited implementation of the seismic margin method, which emphasizes a seismic walkdown and evaluation of outliers with respect to the design basis level, and which is to serve as the seismic IPEEE assessment approach for a specified group of nuclear power plants. (NUREG-1407 assigned plants to this category on the basis that they are located in areas that have a low seismic hazard.) The plants in this category do not need to perform HCLPF calculations, an assessment of soil failures, or a relay evaluation (beyond the requirements of USI A-46, if applicable).

Relay chatter — the oscillation of relay contacts between open and closed positions during a seismic event.

Remote shutdown panel (RSP) — the capability to achieve safe shutdown from outside the control room. While the term "remote shutdown panel" is commonly used both in this report and elsewhere, the term is inaccurate if not somewhat misleading. Plants are required to have a capability to achieve a safe, cold shutdown from outside the control room. In many cases, this is accomplished at one location, thus explaining the common usage of remote shutdown "panel." However, there is no actual requirement for any new or special panel to be used in the event of a fire in the control room. Thus, any mention in this report of RSP should be understood to be a general reference to the capability of achieving safe shutdown from outside the control room, rather than the existence of a specific panel (or panels).

Request for additional information (RAI) — an inquiry sent to a licensee from the NRC for the purpose of obtaining additional information that clarifies the IPEEE submittal.

Review-level earthquake (RLE) — the specific earthquake level recommended in NUREG-1407 for which a seismic evaluation is conducted. This earthquake level governs the criteria that are applied in screening components. In addition, for seismic margin assessments, this earthquake level defines the spectral acceleration values (based on the spectral shape defined by NUREG/CR-0098) from which the seismic demands are derived for use in calculating HCLPF capacities of components. (For seismic PRAs, NUREG-1407 indicates use of the site-specific 10,000-year median uniform hazard spectral shape for developing seismic demands.)

Roof ponding — the accumulation of rain water on the roof of a structure. The term "roof ponding" also pertains to the specific phenomenon in which roof ponding loads lead to sagging (vertical deformations associated with flexure) of the roof that, in turn, leads to additional collection/ponding of water and correspondingly increased loads, potentially resulting in roof instability or failure.

Safe shutdown earthquake (SSE) — the design basis earthquake defined for a nuclear power plant, in accordance with Appendix A to 10 CFR Part 100.

Safe shutdown earthquake (SSE) spectrum — the ground response spectrum associated with a safe shutdown earthquake.

Safe shutdown equipment list (SSEL) — the list of components required for safe shutdown in the event of a specific initiator.

Safe shutdown model — a mathematical representation of the behavior of plant systems, components, and actions that are needed to bring a plant to safe shutdown.

Safety-related structures, systems, and components — those structures, systems, and components that are relied upon to remain functional during and following design basis events to ensure the integrity of the reactor coolant pressure boundary, the capability to shut down the reactor and maintain it in a safe shutdown condition, or the capability to prevent or mitigate the consequences of accidents that could results in potential offsite exposure comparable to the guidelines in 10 CFR 50.34(a)(1) or 10 CFR 100.11.

Scaling factor — a number used to adjust (multiply) the seismic demands determined from some previously performed (e.g., design or reevaluation) building response analysis, in order to estimate the demands associated with a seismic margin earthquake (SME).

Screening analysis — a quantitative or qualitative evaluation used to narrow the list of items that require more detailed assessment. (In a seismic assessment, a screening analysis based on a walkdown and/or documentation review, supplemented by anchorage calculations, is typically performed in order to identify components that require further treatment (e.g., HCLPF or fragility calculations). In a fire assessment, a screening analysis is performed to eliminate fire areas and/or zones that have a negligible CDF contribution. In an HFO assessment, an initial overall screening analysis is performed to exclude hazard categories that have negligible CDF contributions.)

Seismic capacity — the highest seismic demand level (e.g., peak ground acceleration) that a structure, system, or component can withstand and still continue to perform its intended function.

Seismic Category 1 structure — a structure designed to withstand a safe shutdown earthquake (also simply referred to as a Category 1 structure).

Seismic demand — the influences (e.g., stresses and strains, or accelerations/forces and deformations) experienced within (or by) a structure and/or imposed on equipment, as a result of an applied earthquake loading/input. (Seismic demands on equipment are typically characterized by means of in-structure response spectra, or for ground-mounted equipment, the input ground response spectrum. Seismic demands on structures can also be characterized by the input ground response spectrum, although the forces or deformations that are experienced at a particular critical location in the structure (e.g., shear forces on a roof diaphragm) usually provide a more meaningful and precise description of the seismic demand.)

Seismic-fire interaction evaluation — an assessment of seismically induced fires, including the inadvertent actuation of fire protection systems.

Seismic-flood interaction evaluation — an assessment of the effects of a seismic event on the potential occurrence of a flood and plant response to flooding.

Seismic hazard — any feature capable of causing ground motion, and any phenomenon related to, or caused by, ground shaking (e.g., ground movement, liquefaction, landsliding, seiche), which has the potential to produce adverse effects.

Seismic margin — the ability of a plant, system, component, or structure to safely withstand seismic demands or input ground-motion levels beyond those imposed by the design basis earthquake.

Seismic margin assessment (SMA) — a methodology for assessing the seismic capacities and seismic margin of a nuclear power plant. (As described in NUREG-1407, two NRC and EPRI have independently developed two alternative approaches for performing SMA.)

Seismic margin earthquake (SME) — the specific earthquake ground motion spectrum used as input for a seismic margin assessment.

Seismic margin methodology (SMM) — (See "Seismic margin assessment (SMA).")

Seismic PRA (SPRA) methodology — an analytical process used to estimate a plant's frequency of core damage as the result of seismic events. (See also "Probabilistic risk assessment (PRA) methodology.")

Seismic Qualification Utilities Group (SQUG) — a group of nuclear power plant owners who have worked together to pool their experience data on component behavior in past earthquakes, and have sponsored the development of the "Generic Implementation Procedure for Seismic Verification of Nuclear Power Plant Equipment." (See also "Generic implementation procedure (GIP).")

Senior review board (SRB) — a panel of independent experts, consisting of NRC staff and consultants from national laboratories, that performed peer reviews of each IPEEE review in order to ensure the consistency and completeness of the review process.

Sensitivity analysis — an assessment in which one or more input parameters are varied in order to observe their effects on results.

Settlement — downward movement of the ground surface (or of a building or other facility that is founded on, or within, the ground) as the result of the compaction or consolidation of the underlying soil.

Severe accident — an accident that goes beyond the design basis of the plant and results in core damage.

Severe accident management — the implementation of strategies and guidance developed for incorporation into a plant's emergency response procedures to arrest the progression of an accident sequence, or to prevent or reduce the release of radioactivity into the environment.

Soil liquefaction — a phenomenon in which submerged ground materials (particularly, loose cohesionless soils, and some types of sensitive clays) develop high pore pressures under repeated load cycles (that cause rearrangement of soil structure and diminished resistance between soil grains), with a resulting significant loss of shear strength and development of large shear strains.

Soil-structure interaction (SSI) — the dependent relationship between ground motion and building response, where ground motion affects a building's vibratory behavior, and the building's vibratory response (in turn) alters the characteristics of the ground motion. Soil-structure interaction can have an important influence on the demands experienced by a structure and the equipment housed in or near that structure, particularly for the case of a massive structure having a large foundation. (See also "Free field" and "Ground motion.")

Spatial interaction — a potential adverse influence between plant components as a result of their spatial proximity. (Examples of spatial interactions include pounding of adjacent cabinets, water or chemicals spraying on equipment as a result of activation or breach of overhead fire-suppression lines, and overhead fluorescent light tubes falling and shattering inside open cabinets/panels, among many others.)

Spectral shape — the shape (i.e., plotted pattern that does not change with uniform scaling) of a response spectrum associated with a given ground motion. (See also "Ground motion.")

Spurious actuation — an undesirable actuation of a component or system as a result of an uncontrolled or unintended signal.

Standard Review Plan (SRP) — review guidance for nuclear power plant license applications, as issued by the NRC in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," June 1975.

Station blackout (SBO) — the complete loss of alternating current (ac) electric power to the essential and nonessential switchgear buses in a nuclear power plant (i.e., loss of the offsite electric power system concurrent with a turbine trip and unavailability of the onsite emergency ac power system).

Steam generator tube rupture (SGTR) — a PWR severe accident sequence initiated by the breach of at least one steam generator tube.

Step 1 review — a review of a licensee's IPEEE submittal and associated documentation by the NRC and NRC contractor(s). If needed, the Step 1 review may include one or more RAIs.

Step 2 review — a review of the Tier 2 IPEEE documentation retained for audit (as specified in Section 8.2 of NUREG-1407) and maintained by the licensee at its plant or company offices. If needed, the Step 2 review may include a walkdown to confirm specific features of the plant's configuration or screening basis, as encountered in the licensee's IPEEE submittal or Tier 2 documentation.

Submittal-only review — a review of an IPEEE on the basis of the information in the IPEEE submittal and additional information obtained from the licensee's responses to RAIs.

Success path — a specific combination of safety-system trains that accomplish the four principal functions of reactivity control, reactor pressure control, reactor coolant inventory control, and decay heat removal, and that together are capable of bringing a plant to a stable condition (either hot or cold shutdown) and maintaining that condition for at least 72 hours.

Success path equipment list (SPEL) — the list of components needed to achieve chosen success paths.

Supplemental technical evaluation report — a report prepared by NRC staff or NRC contractors that describes additional technical review findings resulting from consideration of a licensee's responses to a final round of RAIs.

Surrogate element — a representative element used in an SPRA to account for the effects of the components that are screened out during the walkdown and screening phase of the SPRA. The failure of a single surrogate element represents the failures of several screened components.

Systematic Evaluation Program (SEP) — an NRC program for examining plants that were licensed before the agency issued the 1975 SRP guidance on regulatory issues.

Technical evaluation report (TER) — a report that describes the technical findings of the review of a licensee's IPEEE submittal and associated documentation.

Tier 2 documentation — information retained for audit by a licensee, as specified in Section 8.2 of NUREG-1407. In general, Tier 2 documentation consists of information and materials that the licensee used in preparing its IPEEE but did not include in its submittal to the NRC (for example, notebooks and detailed calculations), and that by the licensee keeps at the plant site or the corporate office.

Tornado-generated missile — an object that is lofted and transported by a tornado.

Transient — a perturbation in the state of some system or component at full reactor power that initiates a deviation from the full-power, steady-state operating conditions. Transients that are of interest consist of those where the plant systems cannot respond to the deviation in time to restore the plant to its full-power, steady-state conditions before one or more monitored parameters deviates outside of the acceptable operating bounds. Such parameters that exceed operating bounds will trigger events that lead to a reactor scram, which would then call upon operation of the safety-related core heat removal systems.

Transient combustibles — Combustible materials that can easily be moved or stored either temporarily or on a long-term basis. Transient combustibles are typically associated with maintenance, plant modifications, poor housekeeping, or the temporary accumulation of waste materials or storage within the plant.

Transportation and nearby facility accidents — potentially adverse events that are associated with manmade hazards that may occur sufficiently close to the plant to cause an initiating event. Transportation accidents involve moving vehicles (i.e., planes, ships, barges, trucks, and railroad cars) that pass near the plant and may potentially cause an explosion that results in significant over pressure loads and missiles; impact with plant structures or components; or a release of hazardous material and formation of a traveling vapor cloud with the potential for ignition, explosion, or toxic conditions. Nearby facility accidents involve incidents at industrial facilities located within a local proximity to the plant, with possible release of hazardous materials, rupture of a pipeline carrying a hazardous gas or liquid under pressure, and other undesirable events.

Uncertainty analysis — an evaluation process to quantify the epistemic variability in a PRA estimate which derives from incomplete knowledge in formulating PRA models and incomplete knowledge of input variables.

Uniform hazard spectrum (UHS) — a response spectrum for which there is a constant annual frequency of exceedance of spectral values across all vibration periods. A uniform hazard spectrum is constructed as a plot of independently predicted spectral values — each having a given hazard (i.e., annual exceedance frequency or return period), a given confidence level (e.g., 50th percentile for a median spectrum), and a given damping value (typically 5%) — versus the vibration frequencies (or vibration periods) associated with the spectral values.

Unit — a single nuclear power reactor with its associated structures, systems, and components. (Nuclear power plant sites may have one or more units. At sites having multiple units, some support systems may be shared between units.)

Unresolved safety issue (USI) — according to NUREG-0933, "A Prioritization of Generic Safety Issues," a USI is a matter affecting a number of nuclear power plants that poses important questions concerning the adequacy of existing safety requirements for which a final verification has not yet been developed and which involves conditions that are not likely to be acceptable over the lifetime of the affected plants.

USI A-17 — Unresolved Safety Issue (USI) A-17, "Systems Interaction in Nuclear Power Plants."

USI A-45 — Unresolved Safety Issue (USI) A-45, "Shutdown Decay Heat Removal Requirements."

USI A-46 — Unresolved Safety Issue (USI) A-46, "Verification of Seismic Adequacy of Equipment in Operating Plants," which is intended to assess the seismic ruggedness of safety-related equipment to withstand a safe shutdown earthquake in those plants with construction permit applications docketed before about 1972.

Walkdown — an inspection of local areas within and around a nuclear power plant during which systems, components, structures, hazard sources, etc., are physically located and examined, in order to collect relevant plant information; verify plant configuration; evaluate the potential significance of hazards and adverse configurations; verify the location of important equipment; assess the adequacy of installation/construction, condition, and operating status of equipment; ascertain any environmental effects or system interaction effects on equipment, which could occur during accident conditions. (It should be recognized that the seismic walkdown, fire walkdown, and HFO walkdown each have distinct objectives and procedures, although the walkdown treatment of interactions among these events (e.g., seismic-fire interactions or seismic-flood interactions) usually involves a joint set of objectives and procedures.)

APPENDIX A - GUIDANCE ON IPEEE-RELATED REQUESTS FOR ADDITIONAL INFORMATION

The staff developed and used the following guidelines to determine when to send requests for additional information (RAIs) to licensees in order for the staff to complete its IPEEE reviews.

- It is not possible to conclude that the licensee met the intent of the IPEEE generic letter in one or more particular area(s).
- The response to the RAI is necessary to complete the final assessment of the submittal.
- The methodology and/or data used in the submittal is unacceptable, which could result in incorrect ranking or screening, masking, underestimating, or incorrect evaluation. See Table A.1 below.
- Information in response to the RAI would be likely to uncover a significant problem with the results, such as incorrect ranking or screening, masking, underestimating, or incorrect evaluation. See Table A.1 below.
- A plant has a significant assumption or result that is different from other plants in the same group (and the basis or justification is not provided), which could result in incorrect ranking or screening, masking, underestimating, or incorrect evaluation. See Table A.1 below.

Table A.1: Guidance for issuing RAIs

incorrect ranking or screening; or masking	significant risk contributor
	significant plant vulnerability
	important fire areas
	significant fire scenarios
underestimating	plant fire or seismic CDF
incorrect evaluation	core damage frequency
	containment response
	high-confidence of low-probability of failure (seismic)

In general, the staff did not send RAIs under the following circumstances.

- There could be a potential weakness, but the response to the RAI would not add to the review or would not provide any significant additional insights.

- Information provided in response to the RAI would not contribute to the review or would not impact the assessment of the submittal conclusions or vulnerabilities.

- The response to the RAI would not alter the scenario rankings.

- Issuing an RAI to many licensees does not constitute sufficient reason to issue it to another licensee.

- Documentation is weak but, in general, the results are "typical" of what would be expected.

In issuing RAIs, the staff considered the following guidelines.

- The question(s) should be specific. Ask focused questions aimed at a particular issue. For example, do not ask open-ended questions, such as "provide more information about your treatment of human error probabilities (HEPs)." Instead, ask questions, such as "identify the scenarios screened from further analysis based on quantification of HEPs, and discuss how the effects of postulated fires were considered in determining HEPs."

- Ask the question(s) in a way that is clear to the licensee and requests specific information. Avoid asking questions that can be answered "yes" or "no" without providing additional necessary information.

- The RAI should not ask for additional analyses or sensitivity studies, unless such analyses were called for in the IPEEE submittal guidance (i.e., NUREG-1407) and one or more of the guidelines on the previous page apply. Instead, if an assumption or parameter in the submittal appears to be optimistic, provide background related to the issue being addressed, and ask the licensee to either provide a basis for using the parameter in question or repeat the analysis using a value that can be justified.

- Each question should be reviewed by someone other than the author to ensure that it is clear and not subject to alternative interpretations. The reviewer should check each question against the guidelines listed above.

APPENDIX B - GENERIC RAIs RELATED TO THE FIRE PRA IMPLEMENTATION GUIDE

B.1 Background

In preparing their IPEEE, a number of licensees have applied the Fire PRA Implementation Guide (FPRAIG or simply "the Guide"), which the EPRI published in December 1995 [EPRI, 1995]. The FPRAIG provides both general and specific guidelines for performing a fire PRA. The NRC sponsored a review of the FPRAIG from the perspective of the IPEEE program needs [Lambright, 1997]. This review found that (1) the overall fire PRA approach suggested by the FPRAIG is consistent with the current fire PRA state-of-the-art, (2) some of the detailed discussions on fire PRA methods and issues "are an improvement over what can be found in the open literature," and (3) the Guide also provides useful, practical tips, notations, and cautionary statements. However, the review also found that the Guide contains a number of shortcomings "that could potentially lead to either optimistic results or masking of information needed for identifying potential vulnerabilities." The review recommended a set of 15 generic RAI questions that the staff could ask of licensees that employ the FPRAIG.[1] Subsequent IPEEE reviews identified one additional shortcoming that led the staff to add a 16th generic RAI to the list.

Following the FPRAIG review, the NRC and EPRI jointly agreed to an approach for resolving the generic RAIs in a manner that is suitable for the IPEEE program. Consistent with the IPEEE intent, the objective of the resolution approach was not to define nor advance the state-of-the-art but, rather, to ensure that IPEEEs that relied on methods documented in the Guide were capable of identifying plant fire vulnerabilities. This approach led to specific suggestions concerning how licensees should respond to each of the 16 generic RAIs. The following discussions address these generic RAIs, the concerns raised, and the resolution strategies that EPRI ultimately recommended to licensees. Note that the discussion of how the resolution of these issues might have impacted the results or insights of an IPEEE fire analysis is deferred to the body of this report.

B.2 Human Error Probabilities for the Fire Screening Analysis

A licensee's PRA typically credits a variety of human actions, which typically relate to manual actions that are used to recover or bypass a failed system, or to remotely operate a system or component. The internal event models typically include credit for human recovery actions and include an associated human error probability (HEP) for each credited action. These same internal event models are commonly adapted for use in a fire analysis. However, during a fire, some of the recovery actions credited in the internal event analysis might not be possible or might be associated with higher HEP values.

For example, recovery actions that require passage through, or entry into, an area that is impacted by a postulated fire (e.g., the area where the fire occurs or an adjacent area that might be impacted by smoke and heat from a fire) would not typically be credited in the analysis of that fire scenario. Similarly, if the normal path to the location of a credited recovery action is blocked, but an alternate path to the location is available, a higher HEP might be assigned.

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[1] The review also identified a number of concerns that were not reflected in the generic RAIs, either because their verification was deemed not to be essential to the IPEEE process, or because they were deemed not to affect a large number of studies.

In the original guidance provided in the FPRAIG, direct use of the internal event models was allowed for a number of situations. This inherently included credit for all modeled human recovery actions using the internal events HEP values. This neglected the potential impact of fire on the credited operator actions. The primary concern of IPEEE reviewers was that crediting such human actions without review during the fire area/zone screening analysis might lead to premature screening of potentially important fire areas/zones.

The generic RAI asked licensees to explain how fire effects were treated in assessing the reliability of credited human actions and to assess the impact on fire area screening if such actions were not credited. The revised EPRI guidance ultimately recommended that licensees (1) re-examine the human recovery actions credited in the fire analysis to ensure that the actions were possible given the fires being postulated, and (2) assess any potential fire effects on the reliability of the credited actions. One specific issue in fire PRA involves the treatment of operator actions taken within the main control room. For the purposes of the IPEEE process, EPRI recommended that such actions could be assumed to be unaffected by fires outside the main control room.

B.3 Heat Loss Factors and Simplified Hot Gas Layer Modeling

The FIVE method implemented a simplified approach to enclosure fire response modeling, which was also adopted under the FPRAIG. That is, rather than exercising a fire model for each fire scenario, engineering correlations (in the form of tabular worksheets) were adopted to estimate fire plume, ceiling jet, and hot gas layer exposure conditions for a given fire in a given fire zone.

One important aspect of enclosure fire modeling is heat transfer to the enclosure surfaces. Testing has shown that enclosure surfaces absorb a significant amount of heat during a fire, and this moderates the resulting air temperatures within the enclosure. Most enclosure fire models address this behavior through direct modeling of surface heat transfer. The correlations used are generally both complex and time-dependent. One of the significant simplifications invoked in the FIVE/FPRAIG correlations is that heat losses to enclosure surfaces are addressed through a heat loss factor (HLF). The HLF was defined as the fraction of the heat generated by the fire that is assumed to be lost to the enclosure surfaces. Heat lost to the surfaces is not available to heat the air within the room. Under the FIVE/FPRAIG approach, the HLF is assumed to be constant for a given fire scenario, and its value is selected by the analyst.

FIVE recommended using an HLF of 0.7; that is, 70% of the fire's heat is lost to the enclosure surfaces. In the NRC reviews of FIVE,[2] this value appeared to yield reasonable estimates of hot gas layer response. The FPRAIG endorsed the use of these same engineering correlations, but recommended that HLF values ranging from 0.85 to 0.94 were more appropriate. These values were derived from "An Experimental Study of Upper Hot Layer Stratification in Full-Scale Multi-room Fire Scenarios" [Cooper, 1982].

The NRC recommendation for using substantially higher HLF values as a point of potential concern because the HLF directly impacts the assumed plume, hot gas layer, and ceiling jet temperatures obtained from the correlations. For example, with an HLF of 0.94, just 6% of the total fire heat release is assumed to be available to heat the air in the enclosure. In contrast, with an HLF of 0.7, 30% of the total fire heat release is available to heat the air. As a result, raising the HLF from 0.7 to 0.94 meant that only one-fifth as much

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[2] The NRC reviewed the FIVE methodology during its development in the late 1980s, and a part of that review involved comparing of the FIVE hot layer correlations to experimental data.

heat would go into the hot gas layer and, in turn, the predicted hot gas layer temperature increases would be reduced by 80%. The temperature increases in the plume and ceiling jet, but to a lesser degree and in a less predictable manner. This is because the general hot layer temperature increase is only one of the factors in estimating the plume and ceiling jet temperature increases.

In support of efforts to resolve this concern, a series of validation calculations were performed. These calculations were aimed at assessing the impact of changes in the HLF value on estimated hot gas layer temperature, and comparing the correlation's predictions with large-scale fire experiments [Nowlen, 1987]. The results were obtained through a comparison between the maximum hot gas layer temperature predicted by the engineering correlation using three HLF values (0.7, 0.85, and 0.94) to the maximum temperatures measured during full-scale tests over a range of room elevations.[3]

In all cases, an HLF of 0.94 led to significant underestimation of the measured hot gas layer temperature. Using an HLF value of 0.85 also underestimated the hot gas layer temperature for most cases. In only one case did an HLF value of 0.85 yield a predicted temperature increase that fell within the range of the measured data. Use of the FIVE-recommended value of 0.7, however, led to results that compared quite favorably with the test data. In most cases, using an HLF of 0.7 yielded a temperature that modestly bounded the measured data. In four cases, the predicted temperature increase did not fully bound the measured data but, in all such cases, the prediction did fall within the range of the experimental data.

As a second exercise, the actual heat loss factors experienced during two fire test programs were estimated [Nowlen, 1987 and Cline, 1983]. The HLFs in the tests nominally ranged from 0.5 to 0.7. Some limited cases had HLF as low as 0.3. While these results contain considerable uncertainty, they do illustrate a nominal consistency with the correlation results, as described above.

The revised EPRI guidance directs licensees to two possible approaches for responding to the generic RAI. In general, the guidance recommends returning to the original FIVE HLF value of 0.7. The major exception is for cases where the fire source is assumed to be located at or above 40% of the room height. One factor in the hot gas layer correlation is the assumed hot gas layer volume. FIVE recommends that if the fire source is modeled as being elevated above the floor, such as a fire on top of a panel or transformer, only the room volume above the fire source elevation should be assumed to be involved in the hot gas layer. In effect, reducing the room volume tends to offset an increase in the HLF.

B.4 Modeling of Cable Tray Fire Growth

The growth of fire in a stack of cable trays is a common fire PRA scenario. Past practice has generally relied on predictive fire models such as COMPBRN [Ho, 1991] for this analysis. The FPRAIG introduced an approach to modeling the growth of cable tray fires by extrapolating fire test data. In particular, the approach relied on the fire spread behavior noted in a 1976 NRC-sponsored fire test [Klamerus, 1977] as documented by Nowlen [Nowlen, 1989]. Nowlen's description included the approximate time the fire was observed to spread from tray to tray during the test. The FPRAIG recommended using these reported fire spread times as a general model of cable tray fire propagation.

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[3] The correlation can also be exercised in a pseudo-transient format that predicts the temperature increase over time. These results are not illustrated, but follow the same overall pattern of behavior.

A concern with this approach was that it effectively assumes that all cable tray fires will follow the behavior observed in a single test. Of particular concern was the fact that the test in question was designed to simulate a self-ignited cable fire. Hence, no external fire source was present during the period of tray-to-tray fire spread. Application of this limited test result to other fire scenarios appeared to be inappropriate and potentially optimistic, especially for fire scenarios that involved exposure to an external fire source. Furthermore, in applying the FPRAIG guidance, a number of IPEEE analysts assumed that the FPRAIG model also predicted fire damage times. That is, licensees assumed that fire spread was the indicator for thermal damage when, in fact, cables can be damaged before they are ignited.

A review of other cable fire tests [Newman, 1983 and Sumitra, 1982] revealed that cable tray fires could spread substantially faster than was observed in the cited 1976 test, particularly under conditions involving exposure to an external fire. However, EPRI demonstrated that the combination of the tray-to-tray spread model and the FPRAIG-recommended fire heat release rate model for each tray did yield reasonable estimates of the total fire heat release rate for a range of fires, including those cited in the generic RAI. Hence, the resolution of this issue involved something of a compromise.

For the purposes of the IPEEE process, use of the fire spread model recommended in the FPRAIG was found to be acceptable, provided that the fire scenario did not involve substantial exposure to an external fire. Furthermore, the model was only to be used to predict fire heat release rates. An independent assessment of cable damage was also required.

B.5 Main Control Room Abandonment

In a fire PRA, it is common to assume that a severe, unsuppressed fire in the main control room (MCR) will lead operators to abandon the MCR and rely on remote shutdown. The FPRAIG recommended using a conditional probability of abandonment given an MCR fire of 3.4E-3. This value was derived by interpreting data from a small number of actual control room fires and from NRC-sponsored electrical panel fire tests [Chavez, 1987 and 1988]. The interpretation was that operators would have at least 15 minutes after detecting a fire to suppress the fire before a forced abandonment would be required. A further assumption was that, because the MCR is continuously manned by well trained staff, fire detection would occur with little or no significant time delay. In particular, it was assumed that operators would smell a fire with an equal level of reliability and as quickly as would fire detectors that had been optimally placed within the fire source panels during the cited fire tests.

The NRC review of the FPRAIG revealed that the recommended approach did not adequately consider MCR-specific design features. The approach was considered optimistic for some MCRs, including those that do not have in-panel smoke detection available. It was also considered potentially optimistic for MCR configurations that use electrical panels as ventilation system return air plenums. In such cases, smoke from a panel fire would likely be drawn quickly into the ventilation exhaust. There, dilution of the small quantities of smoke associated with the incipient fires observed at the time of detection in the fire tests would mean that ventilation duct smoke detectors would likely not actuate. Under such conditions, the prompt detection times indicated by the test would likely be optimistic when detection in practice relies on operators smelling the smoke from the incipient fire.

An additional complication of this particular generic RAI was the fact that some IPEEE analyses also applied "severity factors" to adjust the MCR fire frequency, typically to reflect prompt detection and suppression of

MCR fires. Because the conditional probability of 3.4E-3 directly credited fire detection and suppression, application of an additional fire severity factor was found, in effect, to represent "double counting" the same mitigating behaviors. Using this approach, a number of IPEEEs screened MCR abandonment scenarios as being risk insignificant, and did not assess the plant's remote shutdown capabilities in the event of a challenging MCR fire. Given the insights gained from past PRAs, and the results of other IPEEEs, the screening of MCRs on such a basis was considered to be potentially optimistic and inappropriate.

The accurate treatment of serious MCR fires and subsequent MCR abandonment is a difficult challenge for fire PRA and, in many regards, is beyond the current state-of-the-art for fire PRA. The IPEEE process was specifically not intended to advance the state-of-the-art. Hence, for the purposes of the IPEEE process, the NRC agreed that licensees could apply the conditional abandonment probability of 3.4E-3 as a nominal estimate of the non-suppression/abandonment probability, but should not apply any severity factors. That is, the likelihood of MCR abandonment was to be taken to be the MCR fire frequency (typically assumed to be 1.9E-2) times the conditional abandonment probability (3.4E-3). The NRC, therefore, directed licensees not to screen MCR abandonment scenarios and to provide an assessment of remote shutdown capability and reliability.

B.6 Recovery of Fixed Fire Suppression Systems

Fixed fire suppression systems are widely used to enhance fire safety in United States nuclear power plants. These systems are also important factors in a fire risk analysis. In fire PRA, it is common to find that fixed fire suppression systems offer a substantial risk benefit. Depending on the timing of system actuation versus critical damage, fire scenarios may be of potential risk importance only if a fire suppression system is assumed to fail on demand (for example, as a result of failures in supporting equipment). Licensees commonly apply generic failure rates to assess the likelihood of such failures.

The FPRAIG included an approach for crediting recovery of a failed fire suppression system. Many types of fire suppression system failures are recoverable. For example, a system inadvertently left in manual actuation mode may be recovered (or actuated) by a simple flip of a switch (provided that no damage to the system has occurred). If fire-fighting personnel arrive on the scene of the fire and find that a fixed suppression system has not actuated, they will likely attempt to recover and/or manually actuate that system.

It was noted that the FPRAIG approach did not address some potential dependencies. In particular, attempts by fire fighters to recover a fixed suppression system would likely delay initiation of other manual fire-fighting actions. If the recovery attempts are not successful, the fire, which would have continued to grow, may present a greater challenge to subsequent manual fire suppression.

EPRI, therefore, provided revised guidance directing licensees to re-examine scenarios that credited both recovery of a failed fixed system and manual fire-fighting. Specifically, licensees were asked to consider the impact of the recovery attempts on the timing of subsequent fire-fighting efforts and the potential for additional fire growth while recovery was attempted. In particular, attention was directed to rooms that are protected by CO_2 or Halon systems. In such cases, fire fighters might be especially hesitant to enter the area knowing that an attempt was being made to actuate the fire suppression system.

B.7 Control Systems Interactions

The fire-induced failure of an electrical cable will lead to some type of circuit fault. How a cable failure will be manifested in the circuit depends on the purpose of the cable in the circuit (i.e., power, instrument or control), the circuit design, and the assumed mode of cable failure. For example, conductor-to-conductor "hot shorts" might lead to spurious component actuations, whereas a short to ground on the same conductors might lead to a loss of system power and/or control. These behaviors, and other related issues, are broadly referred to as control system interaction (CSI) issues.

The CSI issues are also interrelated with the question of fire in the MCR as well as MCR abandonment scenarios. Depending on a plant's safe shutdown strategy, MCR abandonment may be initiated as a result of fires in the MCR itself and/or fires in other critical plant areas (the cable spreading room being a common example). It is important that remote shutdown functions be independent of fire damage and the circuit faults that might occur in such areas.

The treatment of fire-induced CSI is a point of both regulatory and PRA interest. In 1989, the Fire Risk Scoping Study (FRSS) [Lambright, 1989] concluded that the then current fire PRA methods did not fully treat the CSI issues. The CSI issues are arguably one of the most difficult challenges currently facing fire PRA. The potential circuit interactions of interest to fire PRA are complex and difficult to analyze [LaChance, 2000]. The methods of analysis available at the outset of the IPEEE process were both limited and subject to debate.

The FPRAIG provided some guidance for resolving the CSI issues. However, the guidance did not consider all potentially important aspects of the CSI issues. Hence, the NRC developed a generic CSI-related RAI and discussed with EPRI. The generic RAI requested that licensees provide additional discussion and analysis of four specific areas of potential importance to fire PRA. In general, the NRC did not expect licensees to advance the state-of-the-art in their IPEEE analyses. Ultimately it was agreed that licensees' ability to fully address the CSI issues in their IPEEEs was clearly impacted by limitations in the state-of-the-art. Furthermore, a range of related regulatory activities are underway to address CSI concerns. Hence, for the purposes of the IPEEE process, licensees were asked to address one specific aspect of CSI, namely, the independence and reliability of remote shutdown. Licensees were directed to provide an assessment of their remote shutdown capability to ensure that it was independent of fire-induced failures in the areas where fires might force an MCR abandonment, and to assess the capability and reliability of the plant's remote shutdown features.

B.8 Other Fire Risk Scoping Study Issues

In addition to the CSI issues discussed above, the NRC requested that licensees address three issues raised in the FRSS, namely, seismic-fire interactions, smoke control and manual fire-fighting, and the adverse impact of fire suppression systems. In its letter accepting the use of FIVE in the IPEEE process, the NRC noted shortcomings in the guidance for verifying the FRSS issues [U.S. NRC, 1991]. The FPRAIG largely adopted the same guidance regarding these issues as in the FIVE methodology, without addressing the shortcomings identified by the NRC. Hence, the NRC developed three additional generic RAIs, one relating to each of these three issues.

In its response, EPRI provided additional guidance to licensees relating to the three issues. For example, in the area of seismic-fire interactions, EPRI's revised guidance recommended that licensees consider the seismic ruggedness of installed fire suppression systems, the potential for spurious actuation of fire suppression systems, the possible impact of an unsuppressed fire following an earthquake, personnel response to spurious fire alarms that might mask a real alarm, and the impact of spurious suppression system actuations on operator actions required to respond to an earthquake. Licensees were also directed to describe the walkdown approach used to address each issue and document the results obtained in those walkdowns.

B.9 Screening of Fire-Induced Special Initiators

As defined in the FPRAIG, a "special initiator" trips the plant and causes loss of a mitigating safety system. Examples include loss of service water and loss of component cooling water. For some plants, an unrecovered special initiator can lead directly to core damage. Hence, special initiators are potentially significant risk contributors if, as in a fire, there is a potential for common mode failure in multiple mitigating safety systems.

One step in the FPRAIG stated that licensees should "consider the need to locate equipment and cables for those special initiators whose (non-recoverable) frequency is greater than 1E-4/yr." This implied that if the initiation frequency was less than 1E-4/yr, the special initiator scenarios could be screened. A concern with this implied screening criterion is that it might lead to premature screening of potentially important fire risk scenarios. In the worst case, a fire scenario leading directly to core damage (i.e., without additional independent equipment failures) with an initiating frequency of 1E-4/yr would clearly represent a dominant fire risk scenario, if not a fire vulnerability. Following discussion of the concerns, EPRI provided revised guidance that deleted this particular step in the analysis. Licensees were directed to re-examine any fire scenarios that might have been screened using the original guidance.

B.10 Screening of Enclosed Ignition Sources

The FPRAIG process for screening ignition sources was founded on an assessment of the potential that each ignition source might lead to propagation of fire to other combustibles. One aspect of this screening was to "eliminate from further consideration situations where ignition sources are fully enclosed, making them unable to ignite other combustibles." The IPEEE reviewers found that licensees were broadly applying this criterion to screen a range of ignition sources.

Therefore, a concern was raised that this approach might prematurely screen some ignition sources. In particular, some ignition sources have the potential to breach their enclosures. The generic RAI cited transformers and electrical panels as example cases. An electrical panel fire, for example, may generate sufficient heat to warp the panel's doors, thereby allowing fire to escape despite the lack of other openings. Fire experience also includes cases where an energetic electrical fault allowed fires to breach an electrical enclosure.

Following discussion of the issue, EPRI provided revised guidance directing licensees to re-examine a number of fire ignition sources to determine if they were prematurely screened. These sources included transformers of greater than 480V, switchgear, any electrical panel of 480V or greater fed by a high-energy source (such as a diesel generator or transformer) and motor control centers of 480V or greater. With certain specific case-by-case exceptions, licensees were to re-evaluate these sources as "open ignition sources."

B.11 Electrical Control Panel Heat Release Rates

Fire scenarios involving a fire in an electrical panel that threatened overhead cables were quite common in the IPEEE fire analyses. In assessing fire propagation and/or fire damage associated with such fires, the assumed heat release rate (HRR) of the initial panel fire source can be critical. The FPRAIG recommended that most panel fires could be modeled using an HRR of 65 BTU/s (69 kW). This recommendation was primarily based on interpretation of NRC-sponsored electrical control panel fire tests [Chavez, 1987 and 1988].

IPEEE reviewers found that the recommended panel fire HRR may be optimistic for a number of electrical panels because the cited HRR values did not bound the referenced tests, the referenced tests did not address fires involving electrical distribution panels, and the results of other panel fire tests [Mangs, 1994 and 1996] were not considered. The overall concern was that if panel fires were assumed never to exceed 65 BTU/s (69 kW), a fire risk study might prematurely screen some electrical panel fire scenarios.

In response, EPRI provided revised guidance for licensees to use in assessing the fire potential for electrical panels. First, the guidelines established for when it was appropriate to assume an HRR of 65 BTU/s (69 kW). These guidelines reflected the actual test conditions under which panel fire sizes were indeed so limited, namely, panels containing only qualified cables (per IEEE-383 flame spread testing) and panels where the fuel load was concentrated in individual cable bundles such that fire spread beyond a single cable bundle could be dismissed. Second, for all other panels, licensees were directed to reconsider the risk contribution should the HRR be increased to 190 BTU/s (200 kW). The higher HRR value was largely based on the results of the panel fire tests in Finland [Mangs, 1994 and 1996].

B.12 Screening of Fire Sources Based on Non-Combustible Shields

One criterion that the FRAIG cited for screening fire sources was the presence of a non-combustible shield between the source and key targets. IPEEE reviewers found that this criterion would be overly optimistic for some cases, particularly those cases involving high hazard combustibles (such as large oil sources), where flames might impinge on the shield and where hot gases in the plume or hot layer might move around the shield to expose the targets. As a result, licensees might prematurely screen some fire scenarios.

EPRI agreed with these observations, and provided additional guidance for licensees to use in the treatment of non-combustible shields. Specifically, licensees were directed to reconsider any fixed fire sources that were previously screened using the original guidance. In addition, licensees were directed to reconsider fire scenarios that involved potential plume, ceiling jet, and hot layer exposures that would not be impacted by such shields. The revised guidance also notes that it may be appropriate to limit the fire's "damage zone" associated with radiant heat transfer on the basis of the intervention of such shields between the fire and target. However, licensees were directed to take such credit only "if the shield is designed and maintained to protect against the source-target combination being considered."

B.13 Screening of Transient Combustibles

As a general rule, the FPRAIG recommended screening ignition sources if an analysis shows that the source poses no potential for either propagation to secondary fuels or damage to PRA targets. Furthermore, one passage in the FPRAIG stated that "if all fixed ignition sources in a zone screen, the zone probably will screen." IPEEE reviewers noted that some licensees were interpreting this passage as allowing for direct screening of transient ignition sources if all of the fixed ignition sources screened. When applied in this manner, this passage might lead to premature screening of fire zones.

In discussions with EPRI, it became clear that the intent of the FPRAIG authors was not to establish a transient fire screening criterion, and that some licensees were misinterpreting the guidance. The actual intent of the passage was to convey the likely outcome of the transient fire analysis, not to allow for screening of transients. That is, in many situations, transient fire sources do not represent significant fire threats. This is typically attributable to geometry considerations (for example, cables being located too far above the floor for a transient fire source to threaten). Hence, if the fixed sources screen, one might expect the transient sources to screen as well. However, there are cases where this observation does not apply. In particular, the assessment of target vulnerability based on fixed sources alone would be incomplete for areas where there are no significant fixed fire sources, or where the fixed fire sources are not located near the critical targets. In these cases, transient fire sources, which may occur anywhere in the room, might still represent significant fire risk contributors. EPRI, therefore, developed revised guidance to clarify that a specific analysis of transient fire sources is still needed even when the fixed fire sources have screened or are absent. EPRI also directed licensees to re-examine any fire zones that were screened without considering transient fire sources.

B.14 Fire Suppression Criteria

One additional aspect of the FPRAIG treatment of fire suppression led to another generic RAI. Specifically, the FPRAIG provided probabilistic curves for the likelihood of fire suppression versus time for a number of specific fire types (e.g., transients, welding fires, cable fires, panel fires, etc.). In one passage, the FPRAIG stated that fire suppression efforts could be considered successful if the source fire or any subsequently ignited targets were suppressed. The approach estimated the likelihood of successful suppression before damage as the product of two suppression terms, namely, the likelihood that the fire ignition source was suppressed before damage, and the likelihood that any subsequently ignited materials were suppressed before damage. For example, in a scenario involving a panel fire that spreads to overhead cable trays, an analyst might assess the likelihood for fire suppression within a given time as the product of the likelihood that the panel fire is suppressed times the likelihood that a cable fire is suppressed within that time. In effect, the two suppression probabilities are treated as fully independent when, in fact, the two are highly dependent because there is really only one consolidated fire and fire fighters will attack the overall fire, rather than attacking two separate fires.

EPRI provided revised guidance clarify that there is one consolidated fire that requires suppression. The revised guidance states that if the fire does not spread beyond the fire ignition source, the likelihood of suppression is based on suppression of the fire source. However, if the fire does spread, for example to cable trays, the likelihood of suppressing the larger (cable) fire should be used.

B.15 Cable Ignition Temperatures

One aspect of fire growth modeling, as commonly applied in fire PRA, requires the analyst to establish temperature criteria for the ignition of combustible materials. The criteria for piloted ignition of cables (i.e., ignition of cables in the presence of a pilot flame) is a particularly common question encountered in nuclear power plant fire scenarios.

In 1991, an NRC-sponsored cable damage test program revealed that cable electrical failures and arcing often led to self-sustaining fires in the exposed cables [Nowlen, 1991] This lead to a conclusion that the piloted ignition temperature (the electrical sparks representing the pilot source) for the tested cables was at or below the damage threshold for those cables.

The results of the NRC-sponsored tests were cited in the FIVE methodoloy, which recommended that, for cables, the damage temperature and piloted ignition temperature should be assumed to be the same. The most commonly applied value was 700°F (370°C) given the damage thresholds for IEEE-383 qualified cables. The FPRAIG recommended that 932°F (500°C) be used as the threshold for both piloted and spontaneous (i.e., in the absence of a pilot flame) ignition of cables. The higher value derives from earlier EPRI data extrapolation results [Tewarson, 1979]. However, it has since been shown that those extrapolations do not reflect the actual threshold behavior [Nowlen, 1989].

The NRC, therefore, developed a generic RAI to address this change in the assumptions related to piloted cable ignition criteria. Specifically, the RAI stated that using the higher piloted ignition temperature could lead to premature screening of fire growth scenarios. In response, EPRI issued revised guidance recommending that licensees return to the original FIVE guidance.

B.16 References

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APPENDIX C - PUBLIC COMMENTS AND NRC RESPONSES ON DRAFT NUREG-1742

C.1 Introduction

The NRC initially issued NUREG-1742, "Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program," Volumes 1 and 2, in April 2001 as a draft report for public comment, with the comment period ending on July 31, 2001. At that time, the NRC published notices in the *Federal Register*[1] announcing the availability of the report and requesting comments. The NRC also made the report available on the NRC's web site <http://www.nrc.gov/>. The NRC distributed the report to more than 500 people and organizations.

In response to the request for comments, the NRC staff received four letters. Table C.1 lists the authors and organizations who submitted these comments. All comments received are available from the NRC's Agencywide Document Access and Management System (ADAMS) using the accession number listed in Table C.1.

Table C.1: Submitted comments on draft NUREG-1742

Identification #	Organization	Author(s)	Date received by NRC	ADAMS Accession #
1	Nebraska Public Power District	John H. Swailes, V.P. of Nuclear Energy	7/06/01	011910159
2	Rochester Gas & Electric Corporation	Dr. Raymond H.V. Gallucci	7/30/01	012130238
3	BWR Owners Group	J. M. Kenny, BWR Owners' Group Chairman	8/06/01	012190262
4	Union Electric Company	Dave Shafer, Superintendent, Licensing	8/06/01	012190272

In addition to these comments, as part of the IPEEE review process, the staff discussed the approach and results of draft NUREG-1742 with the NRC's Advisory Committee on Reactor Safeguards on June 22 and July 12, 2001.

The final version of NUREG-1742 addresses all of the comments that the NRC received. Specifically, the comments fell into three broad categories:

[1]*Federal Register*, "NUREG-1742, 'Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program'; Draft for Comment," Vol. 66, No. 86, Page 22269, May 3, 2001.

(1) A number of comments were editorial in nature. Such comments are not reproduced in this appendix. However, the NRC corrected the text to reflect these comments where appropriate.

(2) Some comments reflected a difference between the report's representation of a plant feature and the current plant condition. These comments are not reproduced in this appendix. However, the NRC reviewed the comments. The final report was revised to properly reflect the plant feature and the current plant condition.

(3) Other comments related to the presentation of findings and perspectives, the potential uses of the findings, and the plant-to-plant comparisons that could be made. The next section of this appendix summarizes these comments and presents NRC staff's responses.

C.2 Specific Comments and Responses

This section summarizes the comments received, and presents the NRC staff's responses.

(1) **Comment:** The report inappropriately compares core damage frequencies (CDFs) for internal fires, seismic external events, and HFO events with those for internal events. The comment raised the point that the nature of the process for determining the CDFs for the two analyses is significantly different. In the IPEEEs, a conservative screening analyses was performed to look for potential plant vulnerabilities. Even though some aspects of the IPEEE review used PRA techniques, it was still a screening analysis rather than a full-scope PRA. In many cases, conservative assumptions were used to bound the analysis and show that no vulnerabilities exist. In the IPEs, a less conservative, more realistic, assessment was performed. Thus, it is not appropriate to compare the IPEEE CDFs with the IPE CDFs. (Reference: see Table C.1, #3)

Response: It is true that most of the submittals indicated that the IPEEE results were generated using a more conservative approach than employed in the IPE. However, there were also instances where the staff observed that certain assumptions may have been overly optimistic (i.e., non-conservative). While recognizing the uncertainties with any CDF estimate, the staff believe that general comparisons between the IPEEE and IPE CDFs are reasonable. Therefore, NUREG-1742 does not provide plant-specific comparisons or evaluations, but provides general comparisons (e.g., by reactor type). The format for the figures, predominantly in Chapter 3, have been revised to make it clear that plant-specific comparisons are not intended. The "Scope, Limitations, and General Comments" and the "Uses of IPEEE Information" sections in the summary of this report have been revised to clarify the limitations when comparing quantitative CDF results.

The typical fire assessment approach was to perform an initial qualitative screening. Areas that were qualitatively screened would be expected to be areas that would not lead directly to a fire initiation and would not cause the loss of safe shutdown function. To evaluate areas that did not screen, licensees typically applied a PRA approach with variable amounts of uncertainty, detail, and conservatism. Indeed, licensees used some of the IPE PRA information to evaluate the unscreened areas. Similarly in the seismic area, there were different levels of uncertainty and conservatism applied in evaluating seismic capacities. The amount of conservatism varied between analyses and was influenced by the analyst and the method chosen. The NRC staff did not evaluate the amount of conservatism, and it is not clear what level of conservatism could be generically attributed to the IPEEE submittals.

(2) **Comment:** The IPEEE was intended to be a vulnerability screening analysis, rather than a full-scope PRA and, as such, licensees used only the technical resolution needed to support that objective. NUREG-1742 identifies potential uses of the IPEEE information that would need a higher degree of precision than that presented in the IPEEE. Using the IPEEE (with low technical resolution) to resolve issues needing higher technical resolution could result in inaccurate conclusions. Therefore, using the IPEEE information requires careful consideration of the IPEEE objective and how it could affect the results. (Reference: see Table C.1, #3)

Response: We agree that those who use the IPEEE information need to carefully consider both the objective of the activity and the level of detail and completeness of the IPEEE information. We have revised the "Uses of IPEEE Information" in Section 1.4 of NUREG-1742 to emphasize that care needs to be taken when IPEEE information is to be used. Anyone using this information needs to carefully consider the nature, quality, and completeness of the IPEEE analysis to ensure that the analysis is suitable, reasonable, and robust in the context of the desired application.

(3) **Comment:** NUREG-1742 identifies substantial differences in the IPEEE results, without addressing the many differences between the plants' designs and sites. This could be misleading, and could lead to inappropriate conclusions. (Reference: see Table C.1, #3)

Response: We agree. We have enhanced the discussion of the scope of the IPEEEs and the limitations on using this information in the "Scope, Limitations, and General Comments" in Section 1.3 of NUREG-1742.

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Alan M. Rubin, NRC Project Manager

11. ABSTRACT *(200 words or less)*

The NRC requested by Generic Letter 88-20, Supplement 4, and NUREG-1407, that each licensee perform an IPEEE to identify and report all plant-specific vulnerabilities to severe accidents caused by external events. The external events considered included seismic events; internal fires; and high winds, floods, and other external initiating events including transportation or nearby facility accidents and plant-unique hazards. All currently operating U.S. nuclear power plants have completed their assessments.

The objective of the NRC's IPEEE submittal reviews was to ascertain whether the licensees' IPEEE processes were capable of identifying severe accident vulnerabilities to such external events, and implementing cost-effective safety improvements to either eliminate or reduce the impact of those vulnerabilities. The reviews did not attempt to validate or verify the licensees' results.

The purpose of this report is to document the perspectives gleaned from the technical reviews of the IPEEE submittals. These include a description of the overall IPEEE process and findings; conclusions regarding the dominant risk contributors for the major areas of evaluation; an overview of plant improvements; a description of the overall strengths and weaknesses in the licensees' implementation of the IPEEE evaluation methodologies; and an assessment of the overall effectiveness in meeting the IPEEE objectives.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

IPE, IPEEE, Probabilistic Risk Assessment, severe accident, seismic, fire, flood, tornado, earthquake, hurricane, Generic Letter 88-20, NUREG-1407, external events, Fire Induced Vulnerability Evaluation, unresolved safety issue, generic safety issue,

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